

FORESTRY

THE JOURNAL OF THE SOCIETY OF
FORESTERS OF GREAT BRITAIN

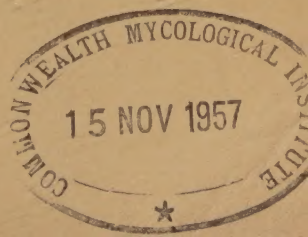
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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects. It is intended that the Society should be representative of the profession. Those not engaged in the practice of forestry or the allied sciences are cordially invited to join as Ordinary Members.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in May and November. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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[continued on inside back cover]



FIG. 1. Clearing a firebreak with the Wilder-Rainthorpe cutter



FIG. 2. Scrub clearing with the 'Swipe' slasher

PLATE IV

Scrub-cutting machines at work in Bagley Wood

See page 122

THE ACHIEVEMENT OF SUSTAINED YIELD BY VARYING THINNING TREATMENT AND ROTATION

By F. C. HUMMEL and A. J. GRAYSON

(Forestry Commission)

SUMMARY

In a forest with a very abnormal age-class distribution it may be possible to achieve a more normal distribution by a number of methods singly or in combination. A worked example is presented showing the implications of different combinations of two methods, namely felling before or after the normal rotation age, and varying the thinning grade. The example taken is a hypothetical block of 1,200 acres which has been planted at the rate of 40 acres a year over a 30-year period and which consists entirely of Norway spruce 2nd quality class. Nine combinations of felling and thinning treatments have been investigated, and for each the development during the conversion period of growing stock, increment, and yields computed. It was found that conversion to a sustained yield presents no particular difficulties, and need involve little sacrifice either in increment, or interest earned on the invested capital, especially if ample time is allowed for achieving normality. In all the nine conversion methods tested, yields rose sooner and fluctuated less than they would have done in the absence of conversion. Choice of method depends on the relative importance which the forest owner attaches to each of several facets of management.

IN many of Britain's new forests the age-class distribution is very abnormal, the oldest stands being only 20 to 30 years older than the youngest; the range of age may thus often be less than half the rotation. The rate of planting in these forests was not related to the probable length of rotation for two good reasons. In the first place it was desirable to bring the available unplanted land into production as quickly as possible; and secondly any calculations based on the area of plantable land available to start with would often have been upset by subsequent acquisitions of plantable land in the neighbourhood.

But if an abnormal age-class distribution is allowed to persist, there will be very great periodic fluctuations in volume yield: yields will be negligible whenever, as is often the case at present, the whole forest consists of young stands; and yields will be abnormally high whenever there is a preponderance of the older age classes. These fluctuations in volume yield will be accompanied by similar fluctuations in money yield and in labour requirements. An abnormal age-class distribution is therefore unsatisfactory to the wood-using industries which need a constant supply of produce, to the owner who needs a regular income, and to the forest workers who want security of employment.

In a previous paper (Hummel, 1956) five methods have been listed by which a transition towards a sustained yield may be achieved: grouping forests in the same neighbourhood to form a single felling series; underplanting or replacing plantations that are unsatisfactory or have failed; taking advantage of the fact that some species grow faster than others and that the rate of growth of any one species will

vary according to the site; felling stands before or after they would normally be considered mature; and finally by varying the thinning treatment.

The advantage of grouping lies in the fact that the age-class distribution for the group as a whole is likely to be less abnormal than in a single forest and a sustained yield will be correspondingly easier to achieve. But unless all forests in the group can serve a common market and be served by the same labour force, the main objects of achieving a sustained yield will be defeated. Grouping may either be permanent or it may be regarded as a temporary expedient in order to allow more time for achieving normality within each forest.

The first steps towards securing a sustained yield may be taken as soon as afforestation begins by planting up the best sites requiring the shortest rotations first and leaving the poorest sites to the last. This sequence of planting has other advantages as well: it is the most profitable, and it is convenient, because the best sites are usually the most accessible.

Underplanting unsatisfactory crops and replacing crops that have failed helps to achieve a sustained yield if done after planting has finished in a forest.

The object of the present paper is to examine in greater detail, by means of a hypothetical example, the other two suggested methods of achieving a sustained yield, i.e. varying rotation length and thinning treatment. In order to concentrate on the possibilities and limitations of these two methods we have assumed a forest consisting entirely of one species and one quality class.

We have chosen Quality Class II Norway spruce for which Hiley (1956) has prepared a yield table for a heavy thinning grade; he has published together with this an extension of the Forestry Commission Yield Table (Hummel and Christie, 1953) for the same Quality Class to 65 years. For the purpose of this exercise volume productions under the two different thinning grades have been extrapolated to 80 years and 100 years respectively. It has been assumed that increments march together. The relevant data of the two yield tables are given in Table I.

In our example we assume that we have an area of 1,200 acres of plantations, laid down over the past 30 years at an annual rate of 40 acres, thus giving 400 acres in each of the 10-year classes: 1-10, 11-20, 21-30. Conversion aims either at a rotation of 60 years applying Hiley's grade (hereafter termed heavy), or at an 80-year rotation using the grade of the Forestry Commission Yield Tables (termed the moderate grade). The resulting mean breast height quarter girths of the main crops at rotation age are $13\frac{1}{2}$ and $12\frac{1}{2}$ inches respectively.

At normality the standing volume is 2,801,000 hoppus feet overall (average 2,330 hoppus feet per acre) for the 60-year rotation and 4,398,000 hoppus feet overall (average 3,670 hoppus feet per acre) for the 80-year rotation. The corresponding increments are 204,500 hoppus feet per annum and 208,350 hoppus feet. These increment values are 7.3 and 4.7 per cent. of the respective growing stocks.

Nine methods of treating the hypothetical 1,200-acre block have been investigated; the first four aim at the 60-year rotation and involve the application of the heavy grade except in method IV which involves both grades, while the other five aim at the 80-year rotation and involve the moderate grade except in

TABLE I. *Yield Tables for Norway Spruce, Quality Class II
Moderate and Heavy Thinning Grades*

Age (years)	Mean Annual increment (H. ft.)	Periodic Annual increment (10 years) (H. ft.)	Forestry Commission				Hiley			
			Main crop		Thinnings		Main crop		Thinnings	
			Volume (H. ft.)	Mean q.g. b.h.	Volume (H. ft.)	Mean q.g. b.h.	Volume (H. ft.)	Mean q.g. b.h.	Volume (H. ft.)	Mean q.g. b.h.
20	67	134	1,250	3½	90	2½	970	4	370	2½
25	93	201	2,000	4½	240	3½	1,730	5½	230	3½
30	112	..	2,650	5	370	4	2,400	6½	350	4½
35	129	232	3,300	5¾	500	4¾	3,060	7½	490	5¾
40	142	..	3,900	6¾	570	5½	3,630	8½	600	7
45	152	233	4,450	7½	620	6½	4,070	9¾	730	8
50	160	..	5,000	8¼	610	7	4,420	11	810	9¼
55	166	222.5	5,505	9	630	7¾	4,660	12	895	10½
60	170	..	5,965	9¾	630	8½	4,790	13½	960	11¼
65	173	199	6,390	10½	615	9½	4,870	15	950	13
70	175	..	6,740	11¼	600	9¾	4,930	16	900	14
75	175	167.5	7,050	11¾	570	10½	4,970	17	855	15
80	174	..	7,310	12½	535	11	5,000	18	750	15¾
85	172	140.5	7,550	13¼	500	11½	..	..	..	..
90	170	..	7,750	13½	465	11¾	..	..	..	..
95	167	107	7,900	13¾	430	12	..	..	..	..
100	164	..	8,000	14	390	12½	..	..	..	..

Note: Figures for ages above 65 years are extrapolated beyond the extended yield tables published by Hiley (1956).

methods VIII and IX which involve both grades. It is assumed that the rate of growth in the whole block of 1,200 acres corresponds to Quality Class II of the yield tables and that it will continue to do so.

In detail, the methods of conversion are as listed below. Table II shows the age classes in which the fellings take place and Fig. 1 illustrates the progress towards normal forest under methods I and IV. The nine methods discussed will lead to a normal forest consisting of even-aged stands if the fellings to be done in any one year are concentrated in a single coupe; alternatively they will lead to a normal forest with a more uneven-aged stand structure if the annual fellings are carried out in small scattered groups. Normality is taken by us to mean a normal age-class distribution which is, in the example chosen, synonymous with a normal size-class distribution. In some contexts, uniformity of size class distribution, rather than of age class, might well be considered more important.

METHODS OF CONVERSION

60-year rotation

- I. Fellings begin immediately at the rate of 200 acres in each 10-year period and they are distributed so as to leave the requisite number of acres (200) in each age class to carry on to the rotation age of 60 years.

This method achieves normality in the shortest possible time (30 years) but involves the greatest amount of felling in immature crops (600 acres in the 21–30-year age class).

KEY

EACH BLOCK REPRESENTS 200 ACRES


 MODERATE
THINNING


 HEAVY
THINNING

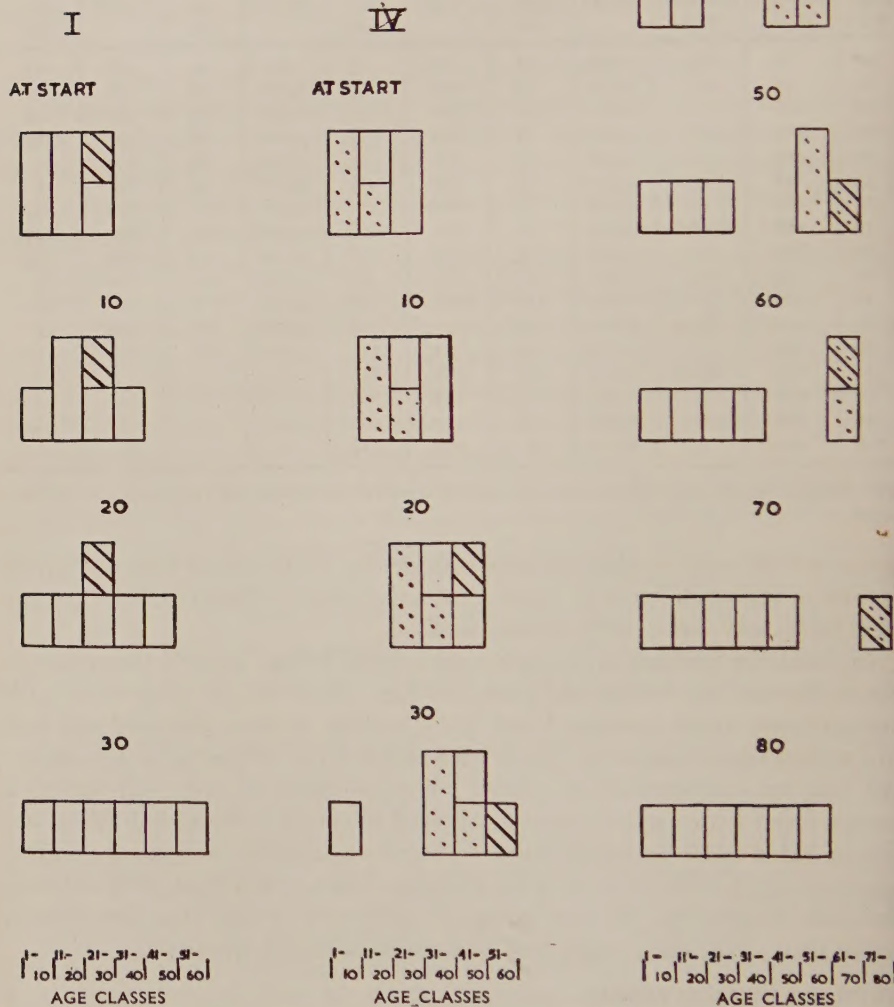

 FELLING
IN PROGRESS


FIG. 1. Diagrammatic representation of conversion methods I and IV showing distribution of areas by age classes at 10-year intervals.

- II. Fellings at the rate of 200 acres per 10-year period begin immediately, but are always carried out in the currently oldest age class.
- III. Fellings begin after a lapse of 20 years and are made, as in II, in the oldest age class at any one time
- IV. Fellings as in III, with, however, the moderate thinning grade applied to the younger half of the forest (i.e. 400 acres at present in age class I-10 and 200 acres in age class 11-20).

80-year rotation

- V. Moderate thinning grade throughout, pattern of fellings as in I, with 150 acres felled in each 10-year period.
- VI. Plan of fellings as in II, but at the rate of 150 acres per 10 years, adopting moderate thinning throughout.
- VII. Plan of felling as in III, but at the rate of 150 acres per 10 years, adopting moderate thinning throughout.
- VIII. Fellings as in VII begin after a lapse of 20 years, but the heavy thinning grade is applied to the older 600 acres of the forest, fellings always in the oldest age class.
- IX. Heavy thinning grade applied to 250 acres of the oldest age class, to 250 of the next oldest, and 100 of the youngest in the existing plantation; fellings begin immediately, always leaving, as in V, the requisite number (150) of acres for the separate age classes of the normal forest.

The fellings described above involve only a statement of area to be felled, and the actual distribution in space of these acreages would of course be a matter for silvicultural decision.

Inspection of Table II shows that the shortest conversion period of 30 years in method I is accompanied by the greatest amount of felling in very immature stands, while the methods involving the longest conversion periods (80 to 100 years) involve the smallest sacrifice of immature timber, some fellings taking place before rotation age and some after.

TABLE II. *Areas and Age Classes in which Fellings Take Place*

Conversion method . .	I	II	III	IV	V	VI	VII	VIII	IX
Conversion period (years) .	30	50	80	80	50	70	100	100	50
Age class	Areas felled in acres								
21-30	600	200	..	..	200	150	..	..	200
31-40	..	400	..	..	350	200	..	..	350
41-50	..	400	200	200	200	250	150	150	200
51-60	..	..	400	400	..	250	200	200	..
61-70	..	..	400	400	..	200	250	250	..
71-80	..	..	200	200	..	..	250	250	..
81-90	..	..	..	..	..	..	200	200	..
91-100	..	..	..	..	..	..	150	150	..

VOLUME CALCULATIONS

In calculating increments, yields, and standing volumes at 10-year intervals in each conversion method the yield table predictions have been used, and suitable allowances must be made if, as might be the case in practice, comparisons of absolute figures were needed. The following further assumptions were made:

(a) Standing volume = acreage in the particular age class multiplied by volume at mid-period (except in the case of the 11-20-year class, where the acreage multiplied by half the volume at 20 years was taken).

(b) Periodic (10 year) annual increment (p.a.i.) = acreage times p.a.i. for the particular age class (but in the case of the 11-20 year class the p.a.i. was taken as the acreage times total crop yield at 20 years divided by 10).

(c) Thinnings volume (annual yield) = one-tenth of the acreage in the particular age class times thinnings yield in that age class (where an area of an age class is being felled the thinning contribution is put at annual acreage times thinning yield up to the middle of the age class; the rest of the thinning yield is shown as felling volume, see (d) below).

(d) Felling volume (annual yield); this is composed of standing volume (main crop) at the end of the age class concerned plus thinnings due during the second half of that age class, and the amount is calculated by multiplying this sum by one-tenth of the acreage in the age class concerned.

The calculation of the volumes obtaining 40 years from the start of conversion, using method VIII, is given as an example in the appendix. (This particular conversion method has been chosen for demonstration of the workings involved, since it is one of the more complicated and brings to notice many of the various combinations of circumstance met with in the methods studied.)

INCREMENTS, YIELDS, AND VOLUMES

Calculation shows that very uneven yields would be obtained if management were to perpetuate the 30-year range of ages by felling only as each individual stand reaches rotation age. Taking as starting-point the 30th year of the scheme, total annual yields would be as follow:

Yield in hoppus feet

Rotation length	Start 0	10	20	30	40	50	60	70	80
60 years	38,000	81,600	128,400	371,000	327,400	281,400	38,000	and so on	
80 years	28,000	70,800	116,400	142,400	148,200	435,600	385,200	340,200	28,000 and so on

These markedly uneven yields (which would of course in practice be less noticeable if advantage were taken of site differences, &c., though we are here concerned with demonstrating the divergences between various courses of management assuming constant growing conditions) contrast with a sustained increment of 204,500 hoppus feet per annum from the normal forest on a 60-year rotation, and an increment of 208,350 hoppus feet adopting the 80-year rotation.

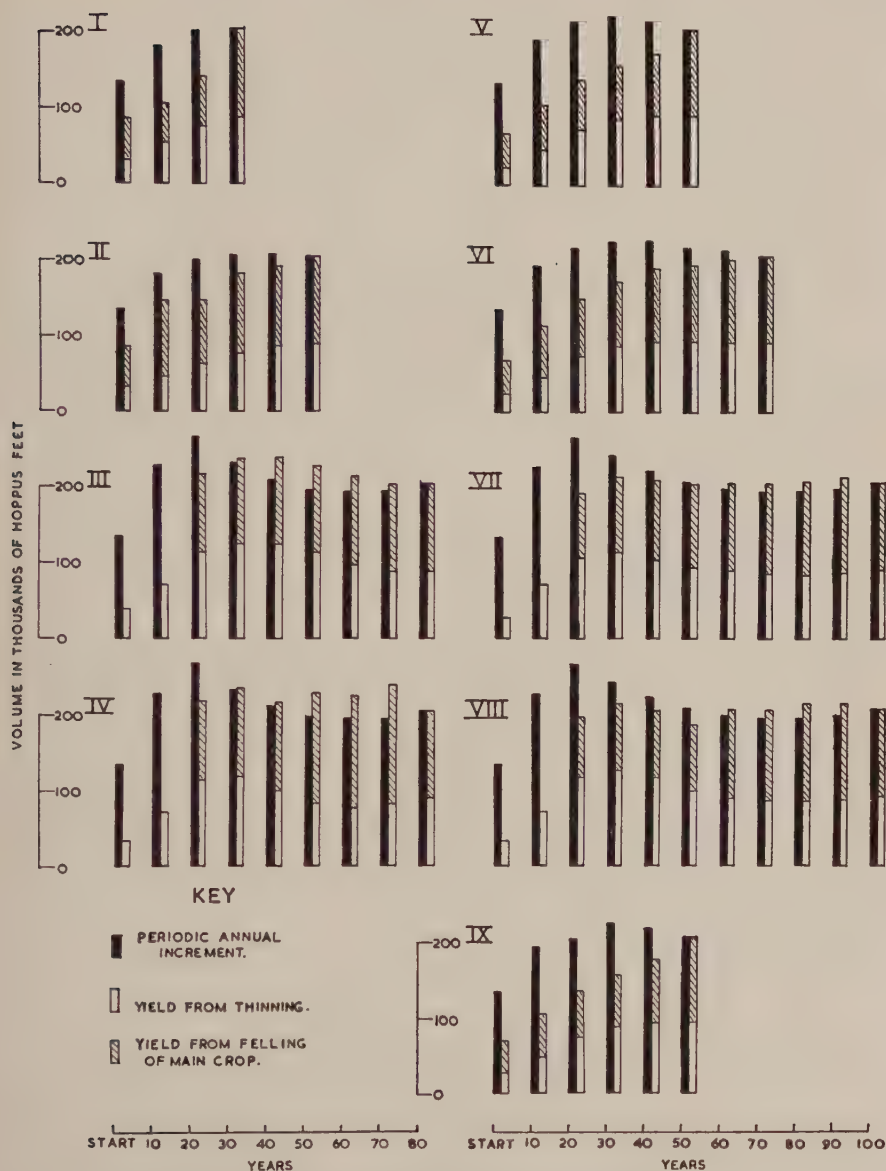


FIG. 2. Increment values and yields for all conversion methods showing levels attained at 10-year intervals.

The increments and yields at 10-year intervals in the various conversion methods are shown in Fig. 2. Under all methods of conversion, yields rise earlier than when there is no conversion and they fluctuate less. This is because all methods used assume some pre-rotation fellings. In methods I, II, V, VI, and IX, in which *all* fellings during the conversion period are pre-rotation fellings, the yields during the first 20 to 30 years of the conversion period are considerably higher than in the other conversion methods; later the position is reversed and in two methods, III and IV, the yield during the latter stages of the conversion period actually exceeds the normal yield. However, even in the methods involving the longest conversion periods the yields do not fluctuate by more than about 20 per cent. after 40 years.

Apart from the fluctuations in yield it is necessary to consider the total long-term loss or gain in total yield which results from the felling of stands before or after the specified normal rotation. Gains may result where the specified normal rotation differs from the rotation of maximum mean annual increment, which is 70 to 75 years in Quality Class II Norway spruce. The mean annual increment at these ages is just over 175 hoppus feet, while at 60 years it is 170 hoppus feet and at 80 years it is 174 hoppus feet.

Below, we first show the total loss of increment due to felling before or after the age of maximum mean annual increment and then we show the loss or gain due to felling away from the specified normal rotation age. This loss or gain is reckoned as the product of acreage felled, age at felling of that area, and the appropriate difference in mean annual increments; this difference is maximum mean annual increment (175 hoppus feet) less m.a.i. at felling age in the first case; and m.a.i. at rotation age less m.a.i. at felling age in the second. These calculations are, of course, separate for each age class and must then be summed. The first is an absolute measure of increment loss, the second is related more to the state of affairs arising in practice where felling at an age different from the rotation age can mean a useful gain in increment achieved. It should be noted that figures in the first instance are comparable for all methods, whereas in the second case, since different standards are used, comparisons are best made only within the two sets of methods I-IV and V-IX.

Increment Gains and Losses

1,000 hoppus feet (+ signifies gain, — loss)

Conversion method	60-year rotation				80-year rotation				
	<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>	<i>V</i>	<i>VI</i>	<i>VII</i>	<i>VIII</i>	<i>IX</i>
Loss related to maximum m.a.i.	—1,134	—1,206	—286	—286	—990	—810	—430	—430	—990
Gain/loss related to m.a.i. at rotation age	—1,044	—996	+104	+104	—960	—756	—358	—358	—960

In terms of the annual increment noted above for the whole forest these figures indicate ranges of losses (where related to the maximum increment) equivalent

to the increment of $1\frac{1}{2}$ to 6 years, and gains or losses (where related to the m.a.i. at rotation age) equivalent to plus the increment of $\frac{1}{2}$ year to minus the increment of 5 years.

Standing volumes are given in Table III. The main point of interest is that in the methods (I, II, V, VI) in which all fellings during the conversion period are at rotation age or earlier the standing volume is gradually built up until the normal growing stock is reached at the end of the conversion period, while in the other methods the growing stock actually increases up to 20 per cent. above the level of the normal growing stock at some stage during conversion. This may be useful where it is desired to combine conversion with the creation of a temporary reserve of growing stock. The influence of thinning régime is shown from the start, the more heavily thinned stands having correspondingly lower standing volumes.

TABLE III. *Standing Volumes, 1,000 boppus feet*

Conversion method	I	II	III	IV	V	VI	VII	VIII	IX
Time from beginning of conversion:									
Start . . .	886	886	886	914	1,050	1,050	1,050	914	948
10 years . . .	1,498	1,498	2,110	2,220	1,875	1,875	2,370	2,164	1,770
20 years . . .	2,215	2,013	3,544	3,700	2,716	2,659	3,900	3,700	2,641
30 years . . .	2,801	2,481	3,784	3,956	3,430	3,271	4,476	4,189	3,387
40 years . . .	..	2,683	3,589	3,910	4,008	3,770	4,715	4,394	4,008
50 years . . .	..	2,801	3,281	3,923	4,398	4,078	4,832	4,604	4,398
60 years . . .	..	..	3,003	3,611	..	4,299	4,855	4,855	..
70 years . . .	..	..	2,863	3,279	..	4,398	4,754	4,754	..
80 years . . .	..	..	2,801	2,801	..	..	4,647	4,647	..
90 years . . .	..	..	..	..	..	..	4,526	4,526	..
100 years . . .	..	..	..	..	..	..	4,398	4,398	..
Totals . . .	7,400	12,362	25,861	28,314	17,477	25,400	44,523	43,145	17,152
Averages for period of conversion . . .	1,850	2,060	2,874	3,146	2,913	3,175	4,047	3,922	2,858
Ditto per acre . . .	1.540	1.720	2.400	2.620	2.430	2.650	3.380	3.270	2.380

FINANCIAL RESULTS

To assess the financial implications of the different conversion methods constant costs and prices have been assumed.

Costs	£/acre
(a) Land value	5
(b) Establishment	60
(c) Cleaning and brashing (incurred at 20 years)	10
(d) Fence and drain maintenance, fire and other protection per annum	1.2
(e) Initial roading at time of planting of 1 mile per square mile (construction cost £2,400/mile)	4

	£/acre
(f) Full road system at 8 miles per square mile	30
(g) Road maintenance at 5 per cent. per annum on initial roadings	0.2
Road maintenance on full system per annum	1.5

(For simplicity in the subsequent calculations, it is assumed that roads are built to the full density at the 20th year of the life of a plantation.)

Prices

The price-size relationship is a crucial one for many arguments on the balance between expenditure and income. At best the figures arrived at can only be estimates of what would be obtained for thinnings and main crop fellings. Data from three sources have been used: F.C. standing sales; returns (unpublished material) from the Prices Survey organized by J. J. MacGregor, F. E. Balman, and T. W. Irvine (Forest Economics Section, Oxford); and, for the form of curve where larger diameters are concerned, data published in Belgium (1955). Using a sample of spruce thinnings sold standing by the Forestry Commission at an average price of 17*d.* per hoppus foot over-bark at a calculated breast height quarter girth (b.h.q.g.) of 5 inches, and by means of a weighted average calculation of data derived from the Oxford Survey indicating a price of 24*d.* per hoppus foot at 7½ inches b.h.q.g., it is possible to fix two points on the curve. The value of stems of 2 inches b.h.q.g. is taken to be nil. Over the same period as the other data (1954-5), it is found that Norway spruce prices in Belgium show that at 15 inches b.h.q.g. 1.3 times the value per cube can be expected over that at 10 inches. It is reasonable to assume that a similar relation will hold in our stumpage values for larger spruce and the final price-size curve has been drawn with this in mind. In order that any error should be on the conservative side and although the data used do involve a proportion of sales of thinnings, the final curve has been assumed for main-crop returns; and for thinnings, a differential of 3*d.* per hoppus foot has been adopted at all quarter girths.

In order to translate the hypothetical volume yields from the tables into real money terms, two reduction factors must be introduced. First, 20 per cent. has been taken as an average figure for short-fall on the predictions of the yield tables; and secondly, 12 per cent. has been allowed for sales overheads. Taken together, these two allowances result in a reduction to 80 per cent. × 88 per cent., or 70.4 per cent. of the basic price, i.e. a reduction of almost exactly 30 per cent.

TABLE IV. *Assumed Prices*

<i>Q.g. class, inches</i>	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Basic price, pence:																
main crop	..	12	17	20	23	25	28	30	32	33	35	36	38	40	41	42
thinnings	..	9	14	17	20	22	25	27	29	30	32	33	35	37	38	39
Multiplier price £:																
main crop	..	0.35	0.50	0.59	0.67	0.74	0.81	0.87	0.93	0.97	1.02	1.06	1.11	1.16	1.20	1.23
thinnings	..	0.26	0.41	0.50	0.58	0.65	0.72	0.78	0.84	0.88	0.93	0.97	1.02	1.07	1.11	..

(Calculation shows that grouping by 3 inch q.g. classes produces erratic results and 1 inch classes have therefore been adopted.) As an example, the calculation of money yields is shown in the appendix for method VIII at 40 years from the start of conversion.

Calculation of costs of management

Using the costs detailed above, the actual costs involved in the different conversion methods are calculable. Table V gives the derivation of charges in a simple case, that of method I.

TABLE V

<i>Nature of operation</i>	<i>At start</i>		<i>At 10 years</i>		<i>At 20 years</i>	
	<i>Quantity acres</i>	<i>Annual charge £</i>	<i>Quantity acres</i>	<i>Annual charge £</i>	<i>Quantity acres</i>	<i>Annual charge £</i>
Brash.	40	400	40	400	20	200
Maintain and protect .	1,200	1,440	1,200	1,440	1,200	1,440
Establish	20	1,200	20	1,200	20	1,200
Build roads at £26 .	40	1,040	40	1,040	..	..
Maintain roads at £0.2	400	80	..	..	..	..
Maintain roads at £1.5	800	1,200	1,200	1,800	1,200	1,800
Total annual charges	..	5,360	..	5,880	..	4,640

From 30 years on (from the start of conversion) the charges are the same as for the 20th year. Comparisons of money income and expenditure at 10-year intervals are given in Table VI.

In order to make possible a complete survey of the financial results of the project from the time of first planting, establishment and associated charges of the plantations are detailed and summed in Table VII. In this, the amounts of expenditure are given by 10-year lump sums, since the charge for land is most easily handled in this way, and subsequent calculations of profitability are thereby facilitated.

If it be assumed that silvicultural, engineering, and protective operations are the concern of a permanent forest staff, it will be seen that (taking £700 per man-year as the total charge—wages, proportion of materials, and so on—associated with each member of the labour force) the range in numbers required stands between 5 and 8 or 9 men; at normality the regular commitment is between 6 and 7 with the 60-year rotation and 6 with the 80-year rotation.

Net money outgoings (indicated by minus signs) and returns are given in Table VIII.

Here it should be noted the net money figures have been inserted as decennial values. On a straight financial assessment, the change from net expenditure to net income occurs between the 10th and 20th years from the start of conversion in all methods except number II, where a small net income is gained by the 10th year. A rather more uneven trend is visible in the net money yields obtained during the longer conversion periods (particularly in methods IV, VII, and VIII) than is apparent in the trends in volume yield shown in Fig. 2. This exaggeration

TABLE VI. *Annual Expenditure and Income*

Time from start of conversion	Conversion method								
	I	II	III	IV	V	VI	VII	VIII	IX
<i>Annual charges £</i>									
At start . . .	5,360	5,360	4,160	4,160	5,060	5,060	4,160	4,160	5,060
10 years . . .	5,880	5,880	4,680	4,680	5,580	5,580	4,680	4,680	5,580
20 " . . .	4,640	4,640	4,440	4,440	4,290	4,290	4,140	4,140	4,290
30 " . . .	4,640	4,640	4,440	4,440	4,290	4,290	4,140	4,140	4,290
40 " . . .	..	4,680	4,460	4,460	4,290	4,290	4,290	4,290	4,290
50 " . . .	..	4,640	4,640	4,640	4,290	4,290	4,290	4,290	4,290
60 " . . .	..	..	4,640	4,640	..	4,290	4,290	4,290	..
70 " . . .	..	..	4,640	4,640	..	..	4,290	4,290	..
80 " . . .	..	..	4,640	4,640	..	..	4,290	4,290	..
90 " . . .	..	..	..	..	..	..	4,290	4,290	..
100 " . . .	..	..	..	..	..	..	4,290	4,290	..
<i>Annual income £</i>									
At start . . .	3,670	3,670	600	600	2,660	2,660	630	600	2,920
10 years . . .	4,760	7,350	2,780	2,800	4,830	5,430	2,770	2,800	4,740
20 " . . .	6,760	8,440	14,840	14,660	6,850	8,050	10,860	13,380	7,700
30 " . . .	16,520	12,540	19,310	18,110	8,940	10,120	14,040	16,150	9,230
40 " . . .	..	13,450	20,250	17,230	11,210	12,780	15,860	17,360	10,450
50 " . . .	..	16,520	21,830	18,120	16,590	13,810	16,180	16,730	16,590
60 " . . .	..	..	20,130	17,680	..	15,410	16,940	16,940	..
70 " . . .	..	..	18,930	19,500	..	16,590	17,200	17,200	..
80 " . . .	..	..	16,520	16,520	..	..	17,690	17,620	..
90 " . . .	..	..	..	..	..	..	18,420	18,420	..
100 " . . .	..	..	..	..	..	..	16,590	16,590	..

TABLE VII. *Expenditure Before Start of Conversion*

Nature of charge	—30 years		—20 years		—10 years	
	Quantity acres	Total charge £	Quantity acres	Total charge £	Quantity acres	Total charge £
For land . . .	..	6,000	..	..	..	..
For basic roads . . .	..	4,800	..	..	..	..
To establish . . .	400	24,000	400	24,000	400	24,000
To maintain plantations	400	4,800	800	9,600	1,200	14,400
To maintain roads:						
at £2 . . .	1,200	2,400	1,200	2,400	800	1,600
at £15 . . .	..	..	..	..	400	6,000
To road building . . .	..	..	..	..	400	10,400
To brash . . .	..	..	..	..	400	4,000
Total . . .		42,000		36,000		60,400

is due to the influence of the larger returns from fellings in older age classes with their contribution of bigger size classes. Among methods I to IV, III and IV reach

TABLE VIII. *Ten-Yearly Net Income or Expenditure (£000)*

Conversion method	I	II	III	IV	V	VI	VII	VIII	IX
-30 years	-42	-42	-42	-42	-42	-42	-42	-42	-42
-20 "	-36	-36	-36	-36	-36	-36	-36	-36	-36
-10 "	-60	-60	-60	-60	-60	-60	-60	-60	-60
Start	-17	-17	-35	-35	-24	-24	-35	-35	-21
10 years	-11	15	-19	-19	-8	-2	-19	-19	-8
20 "	21	38	104	102	26	38	67	92	34
30 "	119	79	149	137	47	58	99	120	49
40 "	..	88	156	126	69	85	116	131	62
50 "	..	119	172	135	123	95	119	124	123
60 "	..	..	155	130	..	111	127	127	..
70 "	..	..	143	149	..	123	129	129	..
80 "	..	..	119	119	..	..	133	133	..
90 "	..	..	..	..	..	..	141	141	..
100 "	..	..	..	..	..	..	123	123	..

a net income of £118,800 per 10 years (the return at normality) earlier than does method I, while in the set V to IX, method number VIII has the edge on V.

Under the heavy thinning régime and 60-year rotation, annual net income at normality = £11,880. This is 4.3 per cent. of the devastation value of forest (growing stock, land, and roads) which is £279,500, and compares with a financial yield of about 3.5 per cent.

Similarly with the moderate thinning régime and 80-year rotation the respective figures are £12,300, 3.2 per cent., £389,700 and a financial yield of 3.0 per cent.

In order to judge the relative attractiveness of the various methods of conversion financially, a calculation of compound interest earned by the plantations from the time of their inception (i.e. 30 years prior to the start of conversion) to the *year when normality is reached* has been made. While compound interest is only one criterion, it is considered that its use here makes for the most satisfactory measure of success in the use of the capital available. Clearly, the amount of capital invested—and the sole variable here is growing stock, since the other amounts involved in items such as roads, fences, &c., are identical in all methods—must be noted in conjunction with the rate earned. The obvious figures to which attention should be paid are those of volume, as shown in Table III.

At normality not only the lump sums of net expenditure or income shown as 10-year figures in Table VIII but also the value of the growing stock and land may be taken into account, and the money returns or charges are each multiplied by the factor $1.0p^n$ where p is the rate of interest applied and n = number of years prior to normality being achieved. The calculation is a crude one, but is adopted here for simplicity in order to provide some measure of the relative earning capacities of the different courses of management which may be adopted. The calculation for conversion method I is shown below.

	<i>Sum to nearest</i>
	<i>£1,000</i>
For $p = 2$,	
$(118,800 + 279,500) \times 1$	= 398,000
$21,200 \times 1.02^{10}$	= 26,000
	<u>£424,000</u>
$11,200 \times 1.02^{20}$	= 17,000
$16,900 \times 1.02^{30}$	= 31,000
$60,400 \times 1.02^{40}$	= 133,000
$36,000 \times 1.02^{50}$	= 97,000
$42,000 \times 1.02^{60}$	= 138,000
	<u>£416,000</u>

Strictly speaking, since an interest charge comes into the calculation of the value of the standing crops the rate used in this valuation should equal that being earned up to normality so that the capital is slightly altered, but the effect of using an assumed rate is very small and may be ignored.

Thus the interest earned up to normality is almost exactly 2 per cent.

The results of similar calculations for the other conversion methods are given along with the average standing volumes during the period of conversion of each example in Table IX.

TABLE IX. *Interest Earned and Average Standing Volumes per acre*

Conversion method . .	<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>	<i>V</i>	<i>VI</i>	<i>VII</i>	<i>VIII</i>	<i>IX</i>
Rate earned (overall) per cent.	2.0	2.4	3.0	2.8	2.2	2.3	2.6	2.8	2.3
Average standing volume during conversion . .	1,540	1,720	2,400	2,620	2,430	2,650	3,380	3,270	2,380

For both the 60-year and 80-year rotations the methods involving heavy pre-rotation fellings (*I*, *II*, *V*, *VI*, and *IX*) and a short conversion period give both lower average standing volumes and lower rates of interest earned than the other methods; but it would be wrong to deduce from this alone that they are necessarily less profitable because the interest rates applicable to the normal forest, i.e. 3.5 per cent. and 3.0 per cent. for the 60- and 80-year rotations respectively, will be earned sooner where the conversion period is short.

It would also be wrong to ignore completely in this study a matter which may often concern management deeply, namely the question of sale of small thinnings. Because of difficulty of access in the early years of working a forest, or for reasons of high cost of extraction even with an amount of roading adequate and economically desirable for the transport of timber considered over the whole life of the stands, or for reasons connected with utilization and marketing, it may be that thinnings under 6 inches b.h.q.g. are unsaleable. Assuming this to be so, but allowing no concomitant alteration in the prices obtained for larger sizes, we find that the reduction in *gross income* under method *III* (the method earning the highest rate of interest) is only 2.2 per cent. In consequence, the rate earned falls

very slightly to about 2.9 per cent. Method I's return is also reduced slightly and becomes a little under 2 per cent. On the other hand, in the methods which involve the use of the moderate grade, the gross income is brought down more sharply; e.g. in case VIII by 6 per cent., thus producing a drop in rate earned to 2.5 per cent. compared with 2.8 per cent. previously, and in case V the drop is from 2.2 to 1.75 per cent.

DISCUSSION AND CONCLUSIONS

The first result that calls for comment is the fact that within a reasonable range of rotation and thinning treatment it is possible to achieve approximately the same yield both in volume and in average size of tree felled with a widely different level of growing stock. In our example the average growing stock per acre for the heavily thinned normal forest worked on a 60-year rotation was 2,330 hoppus feet; in the moderately thinned normal forest worked on an 80-year rotation the volume was 3,670 hoppus feet, or about 50 per cent. more. The difference between these two volumes may be regarded as a 'reserve' of growing stock, because the volume above 2,330 hoppus feet can be removed without appreciably affecting the productive capacity of the forest. In our example the annual increment per acre for the higher level of growing stock is 174 hoppus feet, and for the lower level 170, both being near the maximum of 175 hoppus feet obtainable on a 70–75 year rotation. On purely economic grounds the lower growing stock associated with the heavy thinning régime represents a more efficient use of capital, earning 3.5 per cent. compared with 3.0 per cent. using the moderate thinning grade and longer rotation.

Perhaps the main conclusion to be drawn is that even without any differences in species or quality class the conversion of a very abnormal age-class distribution to normality presents no particular difficulty and may be expected to result in volume yields during the conversion period which rise sooner, but fluctuate less, than they would without conversion. Where the rotation of the normal forest coincides or nearly coincides with the rotation of maximum volume production, conversion involves a slight total loss of increment. In our example this loss varied between $1\frac{1}{2}$ and 6 years increment of the normal forest; but the corresponding losses in yield which result will always be spread over a large part of the conversion period. Where the rotation at normality differs from that of maximum volume production some conversion régimes may even result in a slight gain in yield, amounting in two of our assumed conversion régimes to about half a year's increment of the normal forest.

While there can thus be little doubt that conversion to normality is desirable, no similar definite conclusion is possible about the choice of method, as that will depend on the relative weight that the forest owner attaches to a number of conflicting considerations.

In comparing and contrasting the different methods of converting our hypothetical 1,200 acres to a normal forest, we have drawn attention to different criteria which may be used to judge, from various points of view, the desirability of adopting one course of treatment as compared with another.

The objective measures involved are:

- (i) time to achieve normality;
- (ii) standing volumes held during the course of conversion;
- (iii) increment loss resulting from felling programme;
- (iv) nature (whether gradual or more sudden) of increase in yield;
- (v) time to change over from net expenditure to net income;
- (vi) compound interest rate earned on project as a whole.

It seems clear that the early achievement of normality has, in itself, little to commend it, and criterion (i) has little worth. (ii) may well be most important in the case of the nation's woods, more so than applies with privately owned forests where simple return on outlay plays a bigger role. However, consideration of this measure cannot be divorced from the business efficiency of the enterprise as indicated by (vi). Factor (iii)'s import is difficult to assess. One year's increment at normality over the whole forest is about 200,000 hoppus feet, while the increment losses vary between 1.4 and 5.9 times this amount. (iv) is of significance only in the wider context of outside marketing possibilities (including the practicability in the first place of actually getting the trees felled). Planning of regional outputs such as might be included within the orbit of one group of felling contractors or markets, whichever is the more limiting, is obviously necessary, and little more can be usefully noted on this topic. (v) may have real importance in the individual forest-owner case, but it should not weigh heavily where a large institution (especially the State) is concerned. (vi) on the other hand, it might be argued, has most weight in the private investor case, but in fact the issue is nothing like so clear cut in Great Britain at the present time for reasons of land tenure and land use. For many private owners the area which may be afforested may be limited for reasons connected with land-use policy, finance, or tradition. The State, contrariwise, may be in a freer position when it comes to afforestation; many public authorities can also act more freely. Thus we conclude that, if funds are made available, then the choice both of site to be planted and method of management (choice of species, thinning grade, spatial distribution, rotation length, conversion policy, &c.) are wide and the question of profitability may well count heavily in the programme decided. The weightings to be attached, then, to criteria (ii) and (vi) are the crucial ones. The most readily measurable combination may be held to be that which expresses together cost of growing per cubic foot and the amount grown *and saleable*. However, this measure will not help where a limited area of land is being considered, or in cases where the supply of land (and therefore growth potential) is more limited than the supply of capital and labour that may be devoted to its management. The argument does, however, emphasize that, as with criterion (iv), rate of interest cannot be viewed in isolation, nor can it of course be ignored. We must remember, in fact, the implication of earning a high rate of interest, namely that the cost of production is accordingly reduced (*vide* Hiley, 1956).

If anything, the balance of advantage appears to lie with the slower conversion régimes, which combine higher earning power with higher levels of growing stock

during the period of conversion. This applies with equal force whether the aim is to produce a normal forest by heavy thinning on a 60-year rotation or by moderate thinning in conjunction with an 80-year rotation.

ACKNOWLEDGEMENTS

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APPENDIX

Example of Computations relating to Method VIII (40 years from start of conversion)

Age class	Standing volume		Hoppus feet	Periodic annual increment		Hoppus feet
11-20	$150 \times \frac{1}{2} \times 1,250$	=	93,750	$150 \times \frac{1}{10} \times 1,340$	=	20,100
41-50	$400 \times 4,450$	=	1,780,000	400×233	=	93,200
51-60	$200 \times 5,505$	=	1,101,000	$200 \times 222\frac{1}{2}$	=	44,500
51-60	$200 \times 4,660$	=	932,000	$200 \times 222\frac{1}{2}$	=	44,500
61-70	$100 \times 4,870$	=	487,000	100×199	=	19,900
			<u>4,393,000</u>			<u>222,200</u>

Age class	Annual thinnings yield		Hoppus feet	Mean b.b.q.g.	Value per hoppus foot	Total £
11-20	15×90	=	1,350	..	..	..
41-50	$40 \times (620 + 610)$	=	49,200	$6\frac{1}{2}$	0.050	2,460
51-60	$20 \times (630 + 630)$	=	25,200	$8\frac{1}{2}$	0.065	1,640
51-60	$15 \times (895 + 960)$	=	27,825	$11\frac{1}{2}$	0.084	2,340
55	5×895	=	4,475	$10\frac{1}{2}$	0.078	350
65	10×950	=	9,500	13	0.093	880
			<u>117,550</u>			

Age class	Annual yield from fellings		Hoppus feet	Mean b.b.q.g.	Value per hoppus foot	Total £
51-60	$5 \times (4,790 + 960)$	=	28,750	$13\frac{1}{2}$	0.102	2,930
61-70	$10 \times (4,930 + 900)$	=	58,300	$15\frac{1}{2}$	0.116	6,760
			<u>87,050</u>			

Total annual yield = 204,600 H. ft. Total money yield = £17,360

DEMONSTRATION OF FORESTRY EQUIPMENT

For the past ten years annual demonstrations of new tools and equipment used in forestry have been arranged by the Imperial Forestry Institute and held at Bagley Wood near Oxford. This year the main theme was the development of machinery and tools used in fire protection and in fire-fighting.

The latest type of Hathaway portable pumping unit, which is now used by the Forestry Commission, proved to be capable of producing a jet of 40 gallons per minute through a $\frac{1}{2}$ -inch nozzle and operated effectively at ranges up to 60 yards.

The use of chemical sprays, both in fire-fighting and in pretreating vegetation along fire-lines and forest road sides, was also demonstrated. The chemical used was sodium-calcium-borate, which is produced by Borax Consolidated Ltd. in a form suitable for suspension in water. This is said to be used in the U.S.A. and Canada both directly for grass fires and for spraying from aircraft. Dry brushwood and bracken pretreated with the solution proved to be completely fire resistant at the demonstration but the duration of the effects of this solution after periods of wet weather is unknown.

The clearing and maintenance of fire-breaks or fire-lines by hand tools usually involves high labour costs, particularly in areas of young plantations, and four types of mechanical scrub-cutting machines were demonstrated. The most powerful of these was the Wilder-Rainthorpe new 'Scrub-Masta'. The basic principle of this machine is that the cutting knives are hinged, at the inner end, to a rotor revolving at high speed. Centrifugal force holds the knives straight in a lateral direction, but when an obstacle is encountered the knives can hinge back, thus avoiding breakage. The whole of the rotor is housed in a strong steel housing for the safety of the operator. Various shaped knives can be fitted to the rotor for different types of vegetation. The Scrub-Masta can be hauled by any light tractor. The machine is shown in the illustration facing page 105 (Plate IV, fig. 1) cutting black-thorn and coppice up to 10 feet in height and up to 2 inches in thickness. It pulverizes the chopped material and also crushes and bruises the remaining short stems and this retards regrowth on fire-lines and along the sides of forest rides.

A new cutter from the Wolseley Engineering Co., called 'the Swipe', is a useful slashing machine for the clearing of bracken, bramble, and light scrub and for keeping rides open. This machine depends on the flail action of short heavy chains, spinning round a vertical axle. It has a light steel frame and can be attached directly to a Ferguson tractor, as shown. Its chief merit appeared to be its simplicity and its low cost. The illustration (Plate IV, fig. 2) shows it clearing scrub and ash regeneration up to about 8 feet in height.

The 'Allen' motor-scythe, and a rotary sickle made by the same firm, showed their efficiency in dealing with brambles, bracken, and rough grass. The motor-scythe is a well-known machine for weeding between the rows of young plantations.

Improved models of the Danarm 'Fury' and 'Whipper' chain-saws, both 'one-man' and 'two-man' types, showed a considerable increase in speed and in the efficiency obtained with the new 'chipper' teeth. Similar light-weight chainsaws are used for felling and cross-cutting of timber for removal, when clearing fire-breaks in Canada during fire-fighting operations.

A. H. L.

SOME EFFECTS OF THINNING ON THE SOIL OF A NORWAY SPRUCE PLANTATION

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SUMMARY

Differences in the weight and nutrient content of the litter fall collected at monthly intervals, and in some chemical and physical soil properties, have been studied in the replicated thinning plots of 45-year-old Norway spruce (*Picea abies* Karst.) at Bowmont Forest, Roxburghshire. The B grade thinning is unusually light, and results in increased litter fall and accumulation of organic matter in the forest floor, but differences in litter fall between the heavier grades are small due to changes in crown development. Thinning greatly increases the rate of breakdown of the forest floor and the amount of nutrients available per tree.

The soil under the B grade thinning contains more carbon, organic phosphorus, and available calcium, but differences in more readily available forms of phosphorus and in available cations, other than calcium, are not significant. Leaching of potassium from the surface soil is more intense under the B grade thinning. Of the physical properties studied, only the aggregation of the silt and clay is significantly affected by thinning, the heavier grades leading to a reduction in micro-aggregate stability.

A STUDY of the direct effects of thinning on the volume increment and quality of conifer plantations has necessarily formed an important part of the research programme wherever intensive forestry is practised, but comparatively little detailed work on the indirect effect of thinning on tree growth, by its influence on the soil, has been reported. This is at least partly due to the scarcity of thinning experiments having a sufficient number of replications to allow valid comparison of the differences in soil properties due to silvicultural treatment—differences which, arising over relatively short periods of time in comparison with the development of the soil profile, may be expected to be small in relation to natural soil variability. The sample plots of Norway spruce (*Picea abies* Karst.) established by the Forestry Commission at Bowmont Forest, Roxburghshire, consisting of four thinning grades replicated four times in a Latin square design, afford an unusual opportunity for intensive investigation, and the present paper describes the effect of thinning on the litter fall, the decomposition of the forest floor, and the chemical and physical properties of the surface soil in these plots.

THE SITE

The layout and subsequent silvicultural history of the Bowmont thinning plots have been described by Macdonald (1932) and Hummel (1947). The sixteen square plots, each 0.1 acre in area, are laid out in four rows of four plots, separated from each other by buffer strips 28 feet wide. The four thinning treatments are

selected from those normally used in sample plot work by the Forestry Commission, namely:

- B grade A light low thinning, in which only badly suppressed, dead, and dying trees are removed.
- C grade A moderate low thinning, intermediate between B and D.
- D grade A heavy low thinning, in which only the best trees, mainly dominants, are left and given space for full crown development.
- L.C. grade A light crown thinning. This resembles the D grade, except that suppressed and sub-dominant trees are left to fill the spaces between the best dominants. The bad dominants and co-dominants are removed.

Thinning has been done at regular 5-yearly intervals since 1930. The present study was begun in June 1955, and a thinning was carried out in August of that year, the trees being then 45 years old. Details of the standing crop after this thinning are given in Table I, in which the figures for each thinning grade are the average of four plots.

TABLE I. *Main Crop After 1955 Thinning (from Forestry Commission records)*

Thinning grade	Number of stems per acre	Stems removed in '55 thinning per acre	Average crop height (feet)	Crown* %	Basal area per acre (sq. ft.)	Volume per acre over bark (cu. ft.)
B	1,235	98	49.0	22	230.5	5,561
C	693	107	50.0	30	176.3	4,489
D	207	65	52.0	41	112.5	2,939
L.C.	540	165	48.5	33	136.5	3,366

* Crown % = $\frac{\text{total height} - \frac{1}{2}(\text{base to lowest living branch} + \text{base to lowest living whorl})}{\text{total height}} \times 100.$

The soil is a sandy loam, placed by the Soil Survey of Scotland in the Hobkirk series (freely drained soils derived from Upper Old Red Sandstone drift). On the broad ridge top occupied by the forest the drift is shallow, and is mixed with the underlying decomposing rock. Apart from the differences in the A₀-A₁ horizons which form the subject of this paper, variations in general profile characteristics between the plots are very small. There is very little visible profile differentiation, the soil consisting of a light reddish-brown sandy loam with a soft cloddy structure, darkening slightly with depth, and passing into weathered rotten sandstone, mixed with some drift material, at a depth of about 30 inches. Drainage is good, and living tree roots penetrate the upper layers of the shattered rock freely. Chemical and mechanical analyses of samples from a profile exposed under the D grade thinning, which illustrate the general soil characteristics, are given in Table II.

SAMPLING AND ANALYTICAL METHODS

Samples of the litter falling in each of the sixteen plots were collected at monthly intervals from June 1955 to June 1956, with the exception of August

TABLE II. *Analyses of the Lower Soil Horizons (from Soil Survey of Scotland data, by permission of H.M. Stationery Office)*

Depth (in.)	Mechanical analysis %			Exchangeable cations m.e. per 100 g. soil				pH	Organic fraction %		Phosphorus mg. P per 100 g.	
	Sand	Silt	Clay	Ca	Mg	K	H		C	N	Total	Avail.
2-7	74.4	15.3	6.6	3.24	0.48	0.10	4.10	5.3	1.8	0.13	168	2.6
8-10	77.0	4.8	16.3	2.62	0.26	0.06	1.07	6.0	0.5	0.07	104	1.4
11-16	72.0	5.1	21.1	4.45	0.20	0.14	nil	6.3	0.3	0.05	78	1.4
24-33	68.2	6.1	22.4	4.79	0.18	0.17	nil	6.5	0.2	0.03	70	2.4
36-43	72.2	7.1	19.3	0.81	0.14	0.21	3.09	5.0	0.2	0.01	120	29.2

1955, when thinning was in progress. The samples were collected in metre-square wooden trays placed at the centre of each plot, dried at 80° C., and milled. The nitrogen content of the litter was determined by the semi-micro Kjeldahl method, using a selenium catalyst. After ashing at 450° C., removal of silica by dehydration, and extraction with 0.1 N HCl, phosphorus was determined colorimetrically (Hanson, 1950), and calcium, potassium, and magnesium spectrographically (Mitchell, 1948).

Samples of the forest floor (i.e. all the organic matter on the surface of the mineral soil, in this case the L and F layers of the soil profile, the H layer being extremely poorly developed) were taken from five random points in each plot in June 1955, and treated in the same way.

Soil samples for the determination of total pore space and 'non-capillary' pores (pores drained at 60 cm. water tension) were taken with a core sampler (3 inches diameter $\times$ 2 inches high), also from five points in each plot, and treated according to Low (1954). Spade samples for other determinations were taken to a depth of 2 inches in the A₁ horizon, after the A₀ layer had been removed. These were air-dried and passed through a 2-mm. sieve. The aggregation of the silt and clay fractions (i.e. the proportion of material $< 20 \mu$ in diameter in water-stable aggregates $> 20 \mu$) was determined by the method of Quirk (1950), with suitable adjustment of settling times. Moisture equivalent was measured by centrifuging at 1,000 g.

Total nitrogen in the soil was determined as above, using a mercury catalyst (McKenzie and Wallace, 1954). Available cations (Ca, K, and Mg) were determined spectrographically after leaching with neutral 1 N ammonium acetate, and acid-soluble potassium by boiling with 1 N nitric acid (Reitemeier *et al.* 1948). The phosphorus content of the soil was divided into total, organic, and inorganic fractions by the ignition-acid extraction method recently discussed by Saunders and Williams (1955). Readily soluble phosphorus was also determined, by extraction with 2.5 per cent. acetic acid.

Available (ammonium acetate-soluble) nutrients are reported as m.e. per 100 g. air-dry 2 mm. sieved soil. All other nutrients are expressed as mg. of the element per 100 g. dry material.

RESULTS

Amount of litter fall

The dry weight of litter falling under each thinning grade each month, averaged over four replicates, is given in Table III.

TABLE III. *Monthly Litter Fall under the Different Thinning Grades*
(lb. of oven-dry material per acre)

Thinning grade . . .	B	C	D	L.C.
June 1955	402.9	290.9	292.0	338.4
July	219.7	218.6	218.4	171.4
August*	308.4	307.4	207.4	211.5
September	286.3	291.6	233.1	251.2
October	479.9	411.8	294.5	392.9
November	478.4	378.9	334.2	318.2
December	277.8	210.7	230.6	180.1
January 1956	355.0	303.8	281.2	262.8
February	489.4	296.0	304.2	249.2
March	682.5	420.4	342.4	557.5
April	434.4	290.3	261.2	377.9
May	692.5	430.4	331.1	441.5
June	314.2	198.0	217.5	210.7
Year June '55 to May '56 .	5107.2	3850.8	3330.3	3752.6

* Estimated (see text).

In this table, the figures for August 1955, when thinning was being done, are estimates based on the fall for July and September of the same year, and on a separate collection made in August 1956 after the main experiment was completed. Although the litter fall tends to be heavier under the B grade thinning, differences between plots are large, as might be expected, and monthly differences between thinning grades are only statistically significant in February, March, and May, 1956, when the differences required for significance at the 5 per cent. level are 89.6, 126.9, and 223.5 lb. per acre respectively. Over the whole year, the figure for the B grade thinning is also significantly higher ($P = 0.05$) than those for the other plots. Expressed as litter fall per tree, however, the values are B grade 4 lb., C grade 5.5 lb., D grade 16 lb., and L.C. grade 7 lb. during the twelve months.

Nutrient content of the litter

There are no detectable differences in the nutrient content of the litter from the different thinning grades. Seasonal variations in the nutrient content of the litter were observed, which closely followed those found in Sitka spruce litter by Owen (1954), and the normal seasonal variations known to occur in fresh needles (Wright, 1957). Variations for the plots as a whole are shown in Fig. 1, in which each point represents an average value for all sixteen plots.

It will be seen that the calcium content of the litter, expressed on a dry-weight

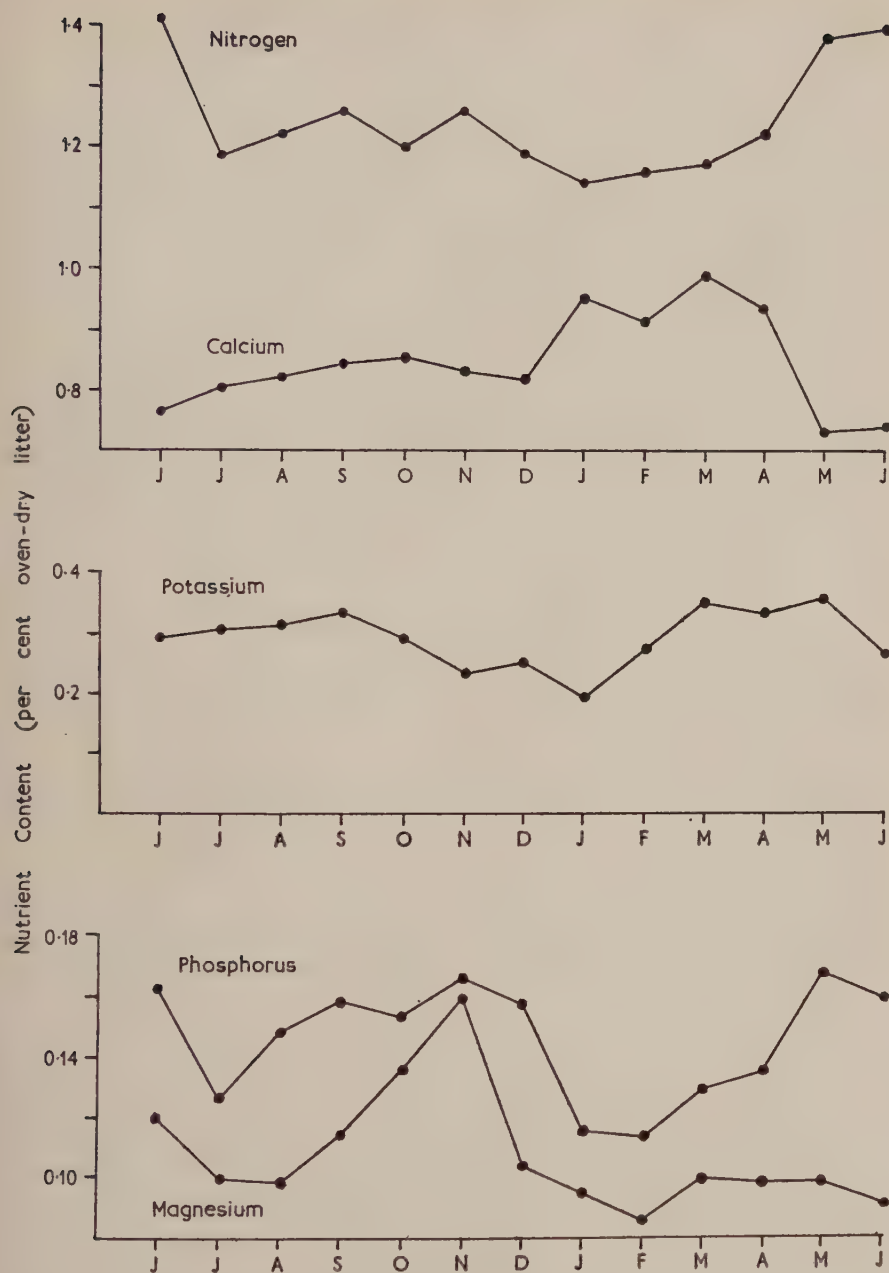


FIG. 1. Monthly variations in nutrient content of the litter.

basis, increases during summer and autumn, while potassium and nitrogen decrease. After a decrease in the summer, phosphorus remains fairly constant during the autumn and early winter, and the magnesium values behave in a similar way.

Mean values for the nutrient content of the litter, averaged over the year, are nitrogen (as % N) 1.23, phosphorus (P) 0.144, potassium (K) 0.29, calcium (Ca) 0.85, magnesium (Mg) 0.11. These values closely resemble those given for third- and fourth-year living needles by Viro (1955), and Tamm (1955), and are similar to Viro's results for fresh litter, except for a higher content of potassium. They are considerably higher than the values given by Viro for old yellow needles, and it would appear from this, and from inspection of the fresh litter, that a considerable proportion of the needles are abscised while still green, before translocation of nutrients, particularly potassium, back into the branches and stem is complete.

A combination of Table III and Fig. 1 gives the total amount of nutrients returned in the litter fall during the year under each thinning grade. These values, expressed on a per acre and a per tree basis, are given in Table IV.

TABLE IV. *Major Nutrients returned to the Soil in One Year*
(lb.)

Thinning	per acre				per tree			
	B	C	D	L.C.	B	C	D	L.C.
Nitrogen (as N) .	63	47	41	46	0.051	0.068	0.198	0.085
Phosphorus (P) .	7.4	5.6	4.8	5.4	0.006	0.008	0.024	0.010
Potassium (K) .	15	11	9.7	11	0.012	0.016	0.046	0.020
Calcium (Ca) .	43	33	28	32	0.035	0.047	0.137	0.059
Magnesium (Mg). .	5.4	4.0	3.5	3.9	0.004	0.006	0.018	0.008

Weight and nutrient content of the forest floor

The dry weights and nutrient content of the forest floor under the different thinning grades, averaged over four replications, are shown in Table V.

TABLE V. *Weight and Nutrient Content of the Forest Floor*
(lb. per acre)

Thinning grade . . .	B	C	D	L.C.
Dry weight* . . .	44,000	23,500	14,900	26,300
Nitrogen (as N) . . .	493	263	167	295
Phosphorus (P) . . .	40.4	21.6	15.4	24.2
Potassium (K) . . .	32.6	17.4	11.0	19.5
Calcium (Ca) . . .	198	106	67	118
Magnesium (Mg) . . .	29.0	15.5	9.8	17.4

* Differences required for significance are:

at P = 0.05, 6,400 lb. per acre.

at P = 0.001, 15,600 lb. per acre.

No significant differences were found in the percentage nutrient content of the forest floor under the different thinning grades. Averages for all sixteen plots, expressed as percent. oven-dry material, were nitrogen (as % N) 1.12, phosphorus (P) 0.092, potassium (K) 0.074, Calcium (Ca) 0.45, and magnesium (Mg) 0.066. Comparison of these values with the average percentage of nutrients in the freshly fallen litter shows that the forest floor as a whole contains 91 per cent. of the nitrogen, 64 per cent. of the phosphorus, 25 per cent. of the potassium, 53 per cent. of the calcium, and 60 per cent. of the magnesium contained in the litter; release of potassium from the fresh material is rapid, whereas nitrogen mineralization is very slow.

Nutrient content and structure of the soil

The results of the chemical and physical analyses of the surface soils (0–2 inches) are only presented for the B, C, and D grade thinnings. Those from the L.C. plots have been omitted because of the lack of uniformity in soil conditions under the irregular canopy of the crown thinning; the samples were found to resemble those from either the B or the D grade plots, according to whether they had been taken from under a group of sub-dominants, casting relatively heavy shade, or from the more open ground under the dominants.

Table VI summarizes the results of the soil analyses. Each figure in the table represents the average of four replicates, and the significance of differences between the thinning grades is indicated.

TABLE VI. *Nutrient Content and Structure of the Surface Soil*

Thinning grade	B	C	D	Difference required for significance at	
				P = 0.05	P = 0.01
Total carbon (% C)	2.25	1.85	1.60	0.34	0.51
Total nitrogen (% N)	0.119	0.120	0.124	Not significant	
C/N ratio	19.42	15.40	12.88	5.04	7.64
Total P (mg./100 g.)	42.4	40.6	36.6	4.4	6.8
Organic P (mg./100 g.)	33.0	31.8	29.0	3.0	4.4
Inorganic P (mg./100 g.)	9.4	9.0	7.6	Not significant	
Acetic-soluble P (mg./100 g.)	1.66	1.28	1.34	Not significant	
Available Ca (me./100 g.)	1.53	1.16	1.08	0.28	0.42
Available Mg (me./100 g.)	0.39	0.37	0.34	Not significant	
Available K (me./100 g.)	0.14	0.14	0.13	Not significant	
Acid-soluble K (mg./100 g.)	14.9	17.4	18.7	2.3	3.5
pH	4.7	4.7	4.7	..	..
Micro-aggregation (%) [*]	18.05	16.70	16.67	1.15	1.74
Moisture equivalent (%)	12.6	12.4	12.8	Not significant	
Non-capillary pore space (%)	17.3	19.3	21.2	Not significant	
Total pore space (%)	60.7	59.6	59.9	Not significant	

* Material < 20 μ in water-stable aggregates > 20 μ expressed as a percentage of the 2 mm. sieved soil.

DISCUSSION

The litter fall

It is well known that the total litter fall varies from year to year, and the figures reported here, being based on only one year's observation, may not give a true value for the plantation as a whole. However, the total annual litter fall of 3,300–3,800 lb. per acre under the C, D, and L.C. thinnings agrees well with the value of 3,360 lb. per acre in a 25-year Norway spruce plantation given by Chandler (1944) and 2,756, 2,920, and 2,540 lb. per acre in older stands (55–68 years) given by Lindbergh and Norming (1943), Mork (1942), and Viro (1955). The considerably higher value for the B grade thinning approaches the figure of 5,900 lb. per acre given for natural, unthinned coniferous forest (45 years old) by Remezov (1956).

The marked periodicity in the amount of litter fall, with the maximum amounts falling in October, November, March, and May, agrees very closely with that observed by Owen (1954) in Sitka spruce. Under Norwegian conditions, Mork found the spring maximum to occur later (June), and the autumn maximum rather earlier (September–October). Farther north, Viro found no evidence of a spring maximum, and only a slight rise in September. The periodicity may therefore be correlated with the length of the growing season, rather than rainfall, as suggested by Mork; it does not appear to be affected by thinning.

Thinning at regular intervals naturally stimulates crown development in the remaining trees, so that the reduction in litter fall to be expected after a thinning, due to the removal of part of the crop, is offset to a large extent by the increased litter fall from the remaining trees. In the present case, the crown per cent. under the D grade thinning is 41, compared with 22 per cent. under the B grade, and the annual litter fall per tree under the D grade is four times that under the B. Although the unusually light B grade thinning results in a significantly greater annual litter fall, differences between the other three grades are very small, due to this compensating effect of increased crown development. Provided, therefore, that some form of economic thinning is practised, whereby a reasonable proportion of the crop is removed, different methods will not alter appreciably the total litter fall, but may considerably affect the litter fall per tree.

The importance of using amounts per tree rather than per acre is apparent when we consider the return of nutrient elements to the soil (Table IV). On an area basis there is very little difference between any of the thinning grades, including B, in the amounts of phosphorus, potassium, and magnesium returned annually to the soil in the litter, although appreciably greater amounts of nitrogen and calcium are returned under the B grade thinning, due to the higher proportions of these elements in the litter. But on a per tree basis the lowest return occurs under the B grade thinning, the forest floor under the D grade receiving four times as much. This improvement in the nutrient supply after thinning is still further increased by the larger volume of soil made available to the remaining crop, and by the decomposition of the roots of the felled trees. Remezov (1953) considers that under pine, the nutrient content of whose litter is low, these two latter effects are among the most important results of thinning.

The forest floor and surface soil

Several authors have drawn attention to the slowness of decomposition of Norway spruce litter in relation to its calcium content, which is higher than that of most other conifers. Plice (1934) has shown that its acidity is high and its buffer capacity low, while Viro (1955) considers that breakdown is retarded by the high oxalic acid content of the needles. Lindbergh and Norming (1943) and Novorossova (1951) have pointed out the high silica content of Norway spruce litter, and the tendency of this species to accumulate large quantities of silica in the forest floor and surface soil. In general, Norway spruce may be considered as a typical mor-forming species, the accumulation of whose litter on the soil surface results in the liberation of large amounts of organic acids and silica, both of which will accelerate the normal processes of soil weathering. Under these conditions, any reduction in the litter fall resulting from thinning will tend to improve soil conditions simply by reducing the amount of these substances reaching the soil, apart from any other effects.

A comparison of the total annual litter fall under the different thinning grades (Table III) and the weight of the forest floor (Table V) also illustrates the important influence of thinning on the rate of decomposition of the organic material, through its effect on the microclimate at the soil surface. The greater litter fall and unfavourable microclimate under the heavy shade of the B grade thinning results in twice the weight of organic material accumulating compared with the C and L.C. plots, and three times that under the D. The large difference in the weights of the forest floor between the C and D plots, whose annual litter fall is very similar, confirms that these are due to different rates of decomposition, and not merely to differences in litter fall.

Comparison of the nutrient contents of the fresh litter and of the forest floor emphasizes the slow release of nitrogen from the organic matter, and the rapid leaching of potassium. The increased speed of decomposition resulting from thinning does not appear to affect the relative rates of release of the various nutrient elements, since the percentage composition of the forest floor is the same under all the thinning grades.

Using total carbon as a measure of the organic matter content of the soil, Table VI shows that thinning decreases the amount of this material in the upper layers of the soil. Differences between the C and D grades, however, do not reach the 5 per cent. level of significance; the more rapid breakdown of the forest floor under the D grade results in a proportionally larger amount of decomposed organic matter being washed down into and mixed with the mineral soil.

Thinning has little effect on the total nitrogen content of the soil since the nitrogen in the forest floor is resistant to breakdown, and a large proportion of the nitrogen decomposed is subjected to biological fixation *in situ*. There is, however, a slight tendency for the nitrogen content of the soil to rise under the heavier thinning grades, due to the greater degree of decomposition of the organic matter. But the marked tendency to superficial rooting in the lower layers of the forest floor visible under the B, and to some extent the C grade thinning, suggests that the nitrogen immobilized in the forest floor is not altogether unavailable to the crop.

Phosphorus accumulates in the surface soil to a greater extent under the B grade thinning than under the heavier grades, but this increase almost entirely consists of organic phosphorus compounds; differences in the inorganic or readily soluble fractions are very small. The organic fraction of soil phosphorus is considered to be only slowly mineralized, and to be relatively unavailable to plants (Williams, 1950). Thus, although a reserve of organic phosphorus may be built up in the soil as a result of light thinning, more readily available forms will be equally plentiful under heavier grades.

Calcium in an 'available' (ammonium acetate-soluble) form accumulates more rapidly under the B grade thinning, as might be expected from the large amounts of calcium in the litter. This extra calcium, however, can only have a limited effect on the microbial activity of the soil, which is already restricted by the adverse microclimate under the heavy shade, and the uniformly low pH value (4.7) under all the thinning grades suggests that its potential benefits are offset by the presence of large amounts of organic acids and silica released from the litter.

There are no significant differences in the amounts of available potassium and magnesium in the surface soil; this is to be expected from Table IV, which shows that, on a per acre basis, thinning has little effect on the relatively small amounts of these elements returned to the soil. However, the potassium fraction dissolved from the soil by Reitemeier's extractant (hot 1 N nitric acid) includes a large proportion of the adsorbed, non-exchangeable potassium, which is resistant to normal leaching, and forms an important reserve of this relatively soluble element in the soil, capable of releasing potassium gradually over long periods of time. This acid-soluble potassium, therefore, indicates the degree of leaching of the more readily soluble nutrients; the values given in Table VI are lower under the B grade thinning than under the heavier grades, in spite of the larger amount of potassium returned in the litter fall, and its rapid extraction from the forest floor, which suggests that leaching is in fact more intense under the B grade thinning than under the heavier grades.

The only physical soil property, of those studied, significantly affected by thinning is the aggregation of the silt and clay. The reduction in micro-aggregate stability under the heavier thinning grades is similar to that observed under agricultural soils consequent on a reduction of organic matter content, and is not considered important in view of the inherently high structural stability of forest soils.

The main effects of thinning on soil properties therefore appear to be a slight reduction in litter fall, a considerable increase in the rate of decomposition of the forest floor resulting from the improvement in microclimate, an increase in the amount of nutrients and rooting space available to the remaining trees, and a reduction in losses of the more soluble nutrients by leaching. The greatest effect is obtained by thinning an excessively dense stand in which litter decomposition is retarded; as the severity of thinning is increased, rates of litter fall and litter decomposition rapidly approach equilibrium values, so that in the heaviest grades the main effect is to increase the rooting volume available to the remaining trees.

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DEVELOPMENTS IN PULPING AND BOARD MANUFACTURE IN GREAT BRITAIN*

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SUMMARY

The development of board and pulp manufacture is discussed in the light of the country's dependence on imports of timber and timber products. The development of board and pulp projects is traced up to the present time, and the individual requirements are briefly examined. The effects of the country's forestry programme, of consumption trends in industry, and of trends in the main exporting countries on the possible future course of home development are discussed. The conclusion is reached that while expansion is likely in both board and pulp manufacture, pulp development may claim greater attention in spite of its more formidable problems. Emphasis is placed on the need for careful planning in the development of the board and pulp industries.

THE development in Britain of the production of board and pulp from timber and timber residues is of recent origin. The extent to which the country is dependent on imports of timber and timber products, either for direct use as in building construction or for further manufacture as in the paper industry, requires no special emphasis; statistics, however subject they may be to differing interpretations, show the general position quite clearly. It is against this background of dependence on imports that wood pulp and board production has developed.

The type and rate of development have no doubt depended on a wide variety of factors which are difficult to assess: for instance, availability of timber; capital cost; economics of production and marketing; competition with other sources of supply and with substitutes; tariff policy; restrictions due to wartime and to balance of payments difficulties. Indeed, the list of factors and their variations could be extended but to no useful purpose so far as this paper is concerned. The main common factor is the supply of timber; the quantity and quality of the material available, and its cost.

Experience in Britain is similar to that of all European countries which are net importers of timber and timber products. The emphasis on making increasing and fuller use of indigenous raw material resources is common to such countries, though the degree of importance attached to such a policy and the ways and means of implementing it vary according to the particular circumstances. This trend in timber importing countries is probably linked to the move in some of the large exporting countries in Europe to process more of their timber and to reduce the export of roundwood.

It is usually accepted that the raw material requirement of board manufacture, compared with pulp production, is less exacting in regard both to the minimum

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economic quantity and to quality. This generalization does not always hold good, but it is a reasonable starting point from which to follow the development of both industries in Britain.

Board manufacture started before the 1939-45 war, and was then based almost wholly on the use of waste timber from wood-using industries and of other vegetable residues. With the conclusion of the war and its immediate aftermath, the board industry turned its attention to the long-term raw material prospects. The country's war-time fellings had made serious inroads into growing stocks in the middle and older age classes, but it was evident that the substantial areas planted in the inter-war years were beginning to yield an appreciable volume of thinnings. In addition a large—that is by Great Britain standards—new programme of afforestation and reforestation had been approved and put in hand. It was, therefore, natural for the board industry to examine the possibility of using thinnings.

There are now three mills in the south of England manufacturing fibre-board on a commercial scale, and using to a great extent small dimension roundwood. In two cases the mills, situated in the London area, are devoted exclusively to the production of board, both hardboard and insulating board; in the case of the third board mill, there are within the compass of the firm's site in Kent a ground-wood pulpmill and a newsprint mill. A relatively new board development, based on home roundwood, has been recently established in Dumfriesshire, Scotland. The product of this factory is chipboard; the process is highly mechanized, and the timber specification is more exacting than for hardboard.

Pulping of home roundwood for the paper and allied industries is on a relatively insignificant scale at present. As in the case of board manufacture, various firms have investigated the possibility of using home timber to produce pulp for use in other manufacturing processes. The paper and rayon industries are the two main users of woodpulp, and their requirements differ substantially. The existing developments indicate clearly the problems and difficulties involved, of which an adequate and steady supply of suitable material at an economical price at mill is of primary importance. There is at present only one pulpmill in Britain—in Kent—using regular supplies of home roundwood to produce woodpulp; the manufacturing process is mechanical, and by far the greater part of the pulpwood requirement is met by imports of roundwood. This mill is integrated with a newsprint mill. A further groundwood mill is planned in Cheshire and is expected to use a substantially greater proportion of home produced pulpwood. Here again the pulpmill will be integrated with the manufacture of newsprint.

Development of chemical or semi-chemical pulpmills based on the use of home-grown timber is, relative to the country's pulp requirements, insignificant. However, progress is being made with a plant to produce bleached hardwood pulp at a site on the border of England and Wales.

One minor use of home pulpwood has been as a substitute for cotton rag in the production of the less expensive grades of linoleum. This can only be considered a marginal outlet for timber, as the level of demand depends largely on the ability of pulpwood to compete with rags on price.

Thinnings in the younger age-classes of coniferous crops provide the main source of material for the board and pulp manufacturers. To some extent there is an overlap in the requirement of the board and the pulp industries, and the requirements of both are in competition with the pitprop market.

In general the boardmills require softwood only though hardwoods such as willow and poplar are usually acceptable. The size of material may range from 2 inches to 12 inches in diameter, and from 2 feet to 14 feet in length. Each firm has its own specification or specifications, but so far as the hardboard industry is concerned some material which is unsuitable for pitprops, either on account of size or straightness, comes within the acceptable limits. On the other hand the main specification for chipboard material is similar to pitprop specifications.

The pulpmill requirements are in some respects more rigid in specification. For groundwood pulp spruces are preferred, though pines and Douglas fir, but not larches, are acceptable. The minimum diameter is $3\frac{1}{2}$ inches (exceptionally $2\frac{1}{2}$ inches), and the length required is 3 feet 6 inches with a downward tolerance of 5 inches. There is little material suitable for groundwood pulpwood which could not be manufactured into round mining timber.

The hardwood pulpwood specification is relatively wide: oak, ash, beech, and birch are the main species sought, but other hardwoods can be used. By comparison with groundwood pulpwood there is a greater tolerance on straightness, though the minimum and maximum diameters are similar.

Neither in the board nor in the pulp industry in this country is it possible to discern a minimum or an optimum size of unit. The smallest board unit has a requirement of 20,000 tons of raw material annually, and the biggest unit runs to 50,000 tons or more. The hardwood pulp project requires a minimum of 36,000 tons annually, and the groundwood mill 50,000 tons and upwards. These figures do not lead to any clear conclusion, and might be regarded only as a rough guide to the order of raw material requirement for initial development.

Consideration of the possible trend of future development must be discussed in the light of the country's forestry programme; of the existing markets for timber and the likely trend of demand by those markets; and of the possible movements in other countries, particularly those which are traditionally exporters of timber and timber products.

The afforestation programme that was carried out between the two Great Wars is producing an increasing amount of timber each year mainly in the form of softwood thinnings of small dimension: the greatly accelerated programme of afforestation and replanting since the last war will begin to make its contribution in little more than 10 years' time. By 1980 softwood thinning production will, it is estimated, be nearly three times its present level. The bulk of this increase will be in the smaller size categories. Hardwood thinning production is unlikely to expand much beyond its present level, though by 1980 the proportion of small sized material is likely to be higher than it is at present.

For small sized softwood thinnings the main traditional markets are the mining, boxmaking, and agricultural industries. It is certain that the reduction in the total use of timber for propping and shoring in the mines in recent years is no passing

phase: modern mining methods, the more economical use of timber, and the further emphasis on fire safety underground will inevitably mean a continuing reduction in the use of timber. There is no likelihood, however, that timber will cease to be used in the mining industry in the foreseeable future, though the fall in total consumption may well be substantial over the next 20 years. The box and crate market is showing a similar trend to the mining timber market, due largely to improvements and economies in packaging methods. In this market the change is generally from timber in one form to timber in another form; it is not the substitution of timber by other basic materials, as in the mining industry. The demand by the agricultural industry is likely to remain steady, though the better treatment of timber, for example by the use of preservatives, may lead to a decline in annual consumption.

As has been mentioned earlier, the trend in the main timber exporting countries is towards more complete manufacture; a simple example is the export of pulp in preference to the export of pulpwod. It is reasonable to expect this trend to continue.

The effect of the forestry programme will be a substantial increase in the production of thinnings, mainly softwood, of relatively small size. At the same time the requirement of such material by the mining and the box and crate industries is likely to decline. Even if allowance is made for the fact that imports are required at present to meet a large part of these needs, there will be surplus production in the foreseeable future: indeed, in some areas that position has been reached. The trend in the timber exporting countries suggests that, in the long term, difficulties may arise in trying to meet increasing requirements of roundwood from abroad. Thus, developments based entirely or substantially on the use of home timber are likely to be more attractive. At first sight it might seem that the development of boardmills, with their lower capital cost and their less exacting requirements in timber specification and quantity, would be the right course. On the other hand, advances in pulping techniques suggest that the gap between the economic minimum requirement of a boardmill and of a pulpmill may be closing: further, the specification for raw material for pulping is widening in certain directions; some species which were considered unsuitable for pulping can now be used; forest and sawmill waste as well as low grade wood also come into the picture.

It would be rash to predict that in the future pulp rather than board development will be the line followed. However, it seems reasonable to suggest that the balance is moving in favour of pulp, if only because of the increase in world demand for paper and paper products and of the country's position in the paper making industry. Existing board manufacturing capacity will almost certainly increase, either by adding to existing units, or by integration with other forms of wood manufacture, or by the establishment of further self-contained units. Pulp development, on the other hand, faces more formidable problems such as effluent disposal, disagreeable odour, supply of water, steam, and power, any one of which may present difficulties which would preclude the establishment of a new mill or at the least make the task of siting a mill extremely difficult.

While the future emphasis will be largely on softwoods, there is certain to be a continuing and expanding interest in the use of hardwoods for pulping.

Careful planning is necessary to the rational development of the board and wood pulp industries. The success of such planning will depend on co-operation among the various sections of the home forestry industry; on co-operation between the forestry industry and the board and paper and pulp industries; and on the reconciliation of local interests in those areas where the combination of factors is favourable to development.

FORESTRY CONFERENCE AT DARTINGTON

IN 1955 and 1956 Timber Conferences, which were held at Attingham Hall near Shrewsbury, have been organized by the Midland Wood Society. These were so successful that Lord Bradford and Sir Henry Beresford-Peirse proposed that a similar conference should be arranged for forestry, and they asked Dartington Hall to organize it.

The conference was arranged for 14th-16th June and, as accommodation was limited, invitations were issued to some twenty-five representatives of forestry, the timber trade, and research organizations. The subject chosen for discussion was 'How should we grow conifers?', and the chairmen and opening speakers were as follows:

'The place of economics in forestry.' Chairman, Lord Bradford. Opening speakers, Mr. W. E. Hiley, Dr. F. C. Hummel. 'Should we grow trees principally for timber or for other purposes?' Chairman, Sir Henry Beresford-Peirse. Opening speakers, Mr. F. G. O. Pearson and Mr. J. J. MacGregor. 'Importance of size of tree, annual ring thickness and knots.' Chairman, Mr. C. J. Venables. Opening speakers, Mr. B. J. Rendle and Mr. Phillip O. Reece. 'Clear-felling versus other silvicultural systems from the standpoints of silviculture, timber quality, extraction and economics.' Chairman, Mr. L. K. Elmhirst. Opening speakers, Mr. J. E. Garfitt and Major D. J. Brodie. 'Thinning methods.' Chairman, Mr. Langshaw Rowland. Opening speakers, Mr. F. Oliver and Mr. J. A. B. Macdonald.

In addition to those named in the programme and those who were connected with Dartington, the visitors included the following, most of whom took part in the debates. Major C. P. Ackers, Messrs. J. L. Benson, C. A. Connell, H. E. Desch, A. J. Grayson, Gordon Jacob, J. W. Lewis, J. D. Matthews, J. L. Pilling, E. G. Richards, P. Sutcliffe, Finlay R. Wilson, S. E. Wilson.

Mr. Grayson acted as rapporteur and it was decided to publish a record of the proceedings, which is likely to be of interest to many British foresters. As the conference was the first of its kind it was necessarily rather experimental, but their general agreement that further such conferences should be arranged is evidence that those who attended it found it interesting and enjoyable. The only criticism that was publicly expressed was that the scope of the debates was too wide and that the subject of each of the individual discussions might have been sufficiently large for the whole conference.

W. E. H.

PINUS CONTORTA IN IRELAND, 1955

By ROGER LINES

(Forestry Commission)

SUMMARY

A short study of some of the older plantations of *Pinus contorta*, a species which has been planted freely on infertile soils in Ireland since 1918. The study was made in connexion with planting and with provenance experiments being made with this species in Great Britain. The author distinguishes only three types planted in Ireland, the familiar South Coastal and North Interior types and an intermediate type called Rainer Forest, to which there is no parallel type in Great Britain. The types are discussed under growth rate, site influence, spacing, susceptibility to sawfly attack, mixtures, thinning treatment, and wind blow. In Eire, the fast-growing South Coastal type is preferred and is usually planted pure as a pioneer crop, whereas in Northern Ireland both Coastal and Interior types have often been planted in mixture with *Picea sitchensis*. The choice of type and the practice adopted in Eire seems the more successful.

INTRODUCTION

PINUS CONTORTA has for many years played a greater part in Irish forestry than it has done in Great Britain. Some of the early plantings on poor ground in Eire were seen by W. H. Guillebaud in 1933, and in 1954 seed was collected from some of these stands by the Irish Forest Service and given to the Research Branch of the Forestry Commission for inclusion in provenance experiments.

Interest in the species in Britain has increased considerably since the war, as its growth potentialities on poor ground became better appreciated, and also because large areas of ground unfit for other species had to be planted.

It was therefore decided that a tour of stands of *P. contorta* in Northern Ireland and in Eire would be undertaken in order to study: (1) the growth of the older plantations—particularly of the coastal provenances which are so infrequent in Britain—and to compare them with the older stands in Britain; (2) to revisit the stands recorded by Guillebaud and remark on their progress after 22 years; (3) to record details of the parent stands from which the seed in our provenance experiments was collected; (4) to study the behaviour of the older mixed plantations, and the thinning treatments given to the older pure crops of *P. contorta*. All this had a greater significance since our own *P. contorta* provenance experiments had just been assessed and the writer had studied the morphological variation of different provenances in some detail.

GENERAL HISTORY

P. contorta was first planted as a forest tree at Ballyhoura Forest, County Cork, in 1918, and there are various other small stands planted before 1922, when the present Irish Forest Service began operations. Since then it has been planted fairly extensively in Eire and there are also stands which date from 1922 in Northern Ireland.

At Avondale, County Wicklow, there are the remains of two lines of *P.*

contorta which were planted in 1916. Some were the South Coastal type and some were an Inland type. The former grew extremely vigorously and so much impressed A. C. Forbes (1928), then Chief Inspector of Forests, that he chose this type for most of his subsequent importations. However, some importations of inland provenances were also made and these have almost invariably proved less vigorous. Thus most of the importations in Eire before 1939 came from the coastal regions of Washington or Oregon (the precise origins are usually unknown). This was in sharp contradistinction to the procedure in Britain where most early imports of seed were from the interior of British Columbia. In Northern Ireland the first plantation is at Baronscourt, County Tyrone (1922), but there was very little planting of *P. contorta* before 1930. Apart from this oldest stand one can only guess at the provenance as all seed records before 1930 have been lost. From 1930 to 1940 the imports of seed followed the lead from Great Britain in coming mostly from the interior of British Columbia. A few pounds were imported from the coast of Washington, however, and the stands which have resulted from this seed make up about half those I saw in Northern Ireland.

Seed supplies were generally limited during the war, but since 1946 the seed imports of Britain, Eire, and Northern Ireland have come from very similar sources with large imports from Lulu Island, British Columbia. For some years past Eire have made seed collections from their older stands, but these have not been sufficient to supply the needs of the expanded post-war planting programme.

DESCRIPTION OF TYPES

From British provenance experiments we can distinguish two main types of *P. contorta*: the Inland and the Coastal forms. A closer study enables us to subdivide these on the basis of rapidity of growth and morphological differences into about seven or more subtypes, e.g. North Coastal (Queen Charlotte Islands, &c.); South Coastal (Washington and Oregon coasts); Alaska; Alberta (i.e. east of Rocky Mountains); Skeena River (Terrace region); North Interior: British Columbia (Upper Fraser River and Shuswap Lake region); South Interior: United States of America (Dry Belt, Idaho, &c.). This classification is arbitrary and made chiefly for practical reasons as each type tends to blend into the adjoining types on its boundaries forming an ecocline.

In Ireland I was able to differentiate clearly only three types: (a) South Coastal, (b) North Interior, and (c) 'Rainer Forest' type. The first two were well known to me and showed a variation of form and growth little different to what was already known of their behaviour in Britain, but we have no parallel with the third, 'Rainer Forest' type, here.

(a) *The South Coastal type*

This is characterized by vigorous growth, a tendency towards heavy branching, with many branches per whorl, numerous secondary and tertiary branches giving a bushy appearance which tends to hide the stem; needles which are fairly short and straight, dark in colour, and retained for up to 7 years (see Fig. 1). The bark of older trees is normally dark, thick, and rough. It may be in the form of cubes



FIG. 1. (B. 3248) In foreground Inland *Pinus contorta* (and some Scots pine); behind are Coastal type *P. contorta*. Both crops planted 1937 on deep peat at Pettigo Forest. Inland origin plants have grown slowly and been badly attacked by sawfly. Note typical growth of Coastal origin plants showing good vigour, bushy growth, dense foliage mass, and dark green colour.



FIG. 2. (B. 3232) Mixture of Inland *P. contorta* and Sitka spruce, in ratio of 1 to 2, turf-planted on peat in 1938, at Gortnamoyagh Forest. The pine outgrew the spruce but were badly attacked by sawfly and now appear moribund.



FIG. 3. (B. 3089) Typical 'Rainer Forest' origin trees, planted 1935 on poor sandstone soil after failure of Scots pine at Kilworth Forest. Original spacing was 4 ft. by 4 ft. Average height is 35 ft. Note rapid growth, even stocking, and upswept fastigiate type of branching.

PLATE VII



FIG. 4. (B. 3045) On left, Inland *P. contorta* and Sitka spruce in intimate mixture. On right pure Sitka. Both planted 1940. The vegetation is *Calluna*, *Molinia*, and *Juncus*. Here was seen one of the few cases of a genuine nursing effect by *P. contorta* on Sitka spruce planted on peat. Kesh Forest Compt. 6.

PLATE VIII

or fissured vertically. Very often there is a tendency towards butt sweep or a wavy stem. Male flowers are often produced abundantly, but cones are produced less prolifically than with type (b). Most seed seems to have been supplied by the Manning Seed Co. from the Washington coast.

British imports of this type are the Identity Numbers 28/28, 30/54, 34/40, and 37/55, as well as numerous smaller seed imports. Unfortunately, there are very few pure stands of these identity numbers in existence, as an earlier survey showed.

(b) *North Interior type*

This is the Inland type of *P. contorta* with which all British foresters are familiar. It differs from (a) in being usually (but not without exception) less vigorous in growth, and in having a generally sparse look about its foliage. There are fewer branches per whorl and fewer minor branches so that the stem is often visible. The needles are longer, more yellow-green, and fall earlier (see Fig. 1 foreground, and Fig. 2). The bark of trees up to 25 years old is often very smooth and thin, but there are examples of rough-barked trees and this is probably a provenance character which varies within this general region. Bark is not a good diagnostic feature in *P. contorta*. Stem form is usually good, with very little tendency towards a crooked stem, but forking is often more frequent than with the Coastal type.

In Eire I did not see any stands of this type older than that planted in 1931 at Glenealy Forest, County Wicklow. I saw younger stands at Curracloe, Forth, and Pettigo Forests. The Glenealy seed was almost certainly from the interior of British Columbia, that at Forth is recorded as 'British Columbia'. Elsewhere, there are quite likely stands from the South Interior region, as Manning was supplying seed from East Washington then, but I did not see them.

In Northern Ireland I saw a number of stands of the North Interior type. These were all planted after 1930 and records show them to be all from the interior of British Columbia, though they came from different parts of this province.

All the stands of this type which I saw throughout Ireland showed only minor differences in form and rate of growth when environmental conditions are taken into account.

(c) *The 'Rainer Forest' type*

The seed for the stands of this type was supplied by the Manning Seed Co. and the origin is said to be 'Rainer Forest'. The Forest Service regional classification is 'North West American Coast'. It seems likely that it came from somewhere in the Mount Rainier National Forest. I know of no provenance in British experiments which is like it. It tends towards the fastigate branch habit, with fine branches and a large number of them per whorl (see Fig. 3). The straight shortish needles which stand out stiffly, the coarse bark type, the pointed cone at a small angle to the twig, &c., point to a coastal form. The open habit, lax branching, and poor needle retention point to an inland form. Where trees have had full room for growth they are rather coarse branched with long lower branches.

If from Mount Rainier, it comes from a region with great local climatic variation. The rainfall varies from 20 to 60 inches and there are extremes of climate.

EXTENT OF PLANTING

Both in Northern Ireland and in Eire, the species has in recent years been planted solely on the poorest types of land, but in the early days some sites were planted which nowadays would be thought too good for *P. contorta*, e.g. at Ballinglen Forest (once called Aughrim), County Wicklow, and at Baronscourt, County Tyrone.

My tour included only one forest (Pettigo, County Donegal) in that area of Ireland covered by blanket bog, and this is a comparatively new unit, but I was impressed by the use which had been made of the Coastal type pine on all the poor ground on the tops of the Wicklow hills. For the most part these Wicklow plantations do not lie on deep peat but the trees root down through the thin skin of peat into the rather infertile soil below. The driest slopes have no peat, but a dense cover of *Ulex gallii*, which makes establishment very difficult. The early plantations on the bottom slopes (e.g. of Douglas fir, *Pseudotsuga taxifolia*) grew well, but those on the middle slopes are often complete failures, so that the dense, dark-coloured crops of vigorous coastal *Pinus contorta* on the highest ground contrast vividly with the failed plantations of Scots pine (*P. sylvestris*), Corsican pine (*P. nigra* var. *calabrica*), and European larch (*Larix decidua*) on the mid-slopes. These dwarf gorse sites are still problem areas in Britain.

I was told that in the west of Eire there are large, comparatively recent plantations on deep peat, but what impressed me was the great use made of the species on the poorest ground types with little or no peat in the east. *P. contorta* forms about 15 per cent. of all species planted in Eire.

I saw more *P. contorta* on peatlands in Northern Ireland, where there appears to be no parallel for the barren heaths or 'commons', such as at Forth near Wexford. It seems to be planted in mixture far more than in Eire (where I saw few intentional mixtures) and in this way the stands resemble those in Britain more closely. As in Eire it has been planted usually on the highest and poorest ground in the forest and has everywhere outgrown all other species except for Sitka spruce (*Picea sitchensis*) on the occasional flushes.

In Northern Ireland *Pinus contorta* forms only 7 or 8 per cent. of all the species planted.

GROWTH RATE

About thirty-five stands were examined in some detail. It would therefore be unwise to make any sweeping statements based on such a small, though selected sample; but it is apparent that if one considers soil type, exposure, and elevation there is little difference in the rate of growth seen in Ireland compared with that in Britain. This should be qualified by noting that in a crop of coastal *P. contorta* planted in 1942 at Lough Gill Forest, near Sligo, I saw exceptionally fast growth on the *Luzula* flushes. Some trees were 30 feet tall at 13 years, which is considerably faster growth of this species than anything known in Britain.

(a) *South Coastal type*

Although most of the stands of this type which I saw seemed to be growing vigorously, there was considerable difference in the heights attained owing to extreme variation in ground type and exposure. Thus Compartment 373 at Baronscourt had trees 51 feet tall at 27 years old while a stand of similar provenance 20 years old at Rathdrum, County Wicklow, was only 27 feet tall. The latter occupy a bleak hill-top at nearly 1,500 feet whereas the former are low down and on better ground.

The greatest vigour is shown by the South Coastal type under all conditions of site and soil. It certainly seems to stand exposure at high elevations rather better than the Inland type, e.g. at Glenealy and Rathdrum in the Wicklow Mountains. In the highest parts of comparable compartments, the South Coastal type had closed canopy and killed the vegetation, whereas the Inland type had made nearly as much height growth, but, due to its lighter foliage, had not yet closed canopy. Other examples of the superior height and diameter growth of South Coastal *P. contorta* were seen at Cam, Compartment 81 and in Compartment 27, Springwell Forest, County Londonderry, but it was not often possible to make a direct comparison of growth.

It is interesting to compare the growth of one South Coastal lot in the Mullaghcroy block at Baronscourt Forest, near Newton Stewart, Compartment 201, with plants of the same seed origin in Scotland. The seed was originally purchased from Manning's by the Interim Forest Authority and is known to be of Washington coast origin. The seed was sown at Baumreagh Nursery, County Wicklow, and some 20,000 plants were taken to Baronscourt in Northern Ireland. Some of the plants were presumably planted in Eire, but so far these have not been traced. Of the remainder, some were planted at Mullaghcroy in 1922 and some were sent to Scotland where they were planted at Culbin (Expt. 2 P.22 and Sample Plots S.136 and S.137), at Monaughty (Expt. 4 P.22), and at Inchnacardoch (Expt. 67 P.28). The last two provide little information as the site is so poor at Monaughty that all failed except for a few drainside trees. At Inchnacardoch, *Fomes* and windblow ruined the crop. The latest measurement of the Culbin sample plots gives their top height as about 50 feet and their average girth as 20 inches (C/D grade). A small plot at Dalbeattie Forest has also recently been discovered to be of the same origin. The Mullaghcroy stand is in mixture with Sitka spruce and has suffered quite considerable windblow on this exposed site. Its top height is about 50 feet and average girth is about 24 inches.

I did not see any 'coastal' stands of quite such large dimensions as the *P. contorta* planted in 1912 in the Ruttle Wood, Beaufort Estate, but many of the Irish stands will be just as big in a few years. It is to be hoped that with good treatment they will be saved from the wholesale windblow which the Ruttle stand suffered. There are stands in Eire, such as the area planted in 1918 at Ballyhoura (which I did not see), which must be very large now. In Northern Ireland the most impressive stand was that in Baronscourt Compartment 373

where some trees were up to 42 inches girth with heights over 50 feet at 27 years of age.

(b) *The North Interior type*

The most extensive stand of this type which I saw in Eire was at Glenealy, County Wicklow, in the compartments planted in 1931. This is on a poor peat with *Calluna* on top of (in places) bare rock and elsewhere a stony till. It also endures considerable exposure as it lies on the top of one of the Wicklow foothills at 1,200 to 1,300 feet. On the almost bare rock of the actual summit the crop has failed or is very patchy—probably mountain pine (*Pinus mugo*) would not survive here—but only a short way from the summit brings one to crops 30 feet tall, and showing little sign of ill-health.

O. V. Mooney (1954) of the Irish Forestry Division has been quoted in the *Forestry Commission Journal*, vol. xxiii, p. 31, as follows: 'The fine-branched inland type has not been found effective in Eire where poor and exposed conditions require the use of *Pinus contorta*. It behaves in a manner somewhat like Corsican pine at high elevations and ultimately loses its needles and peters out as does the Corsican pine.'

Unfortunately, I couldn't confirm this as I saw no sites where this had occurred without the added help of sawflies. In fact it would be true to say that, though one might expect earlier closing of canopy and more vigorous growth with Coastal *P. contorta*, the Inland types were not actually unhealthy but merely growing less fast. Although this is not a desirable character, rapidity of growth is not the sole criterion of silvicultural accommodation to the site. If one could find a provenance which combines the rapid growth of South Coastal *P. contorta* with the superior form of the Inland type it would solve a big problem.

In Northern Ireland I was able to compare Inland and Coastal types, both grown in mixture with Sitka spruce. At Cam Forest, County Londonderry, in Compartment 81 there is a crop of Inland *P. contorta* with a strip of South Coastal provenance running through it. Both were planted in 1938 but the former is on average 10 to 12 feet high, while the latter is nearer 20 feet and forming a dense crop. There is still a heavy *Calluna*/*Molinia* cover under the sparsely branched Inland crop. At Springwell Forest, a few miles from Cam, in Compartment 27, planted 1933, the main crop is South Coastal *P. contorta* and Sitka spruce in an intimate mixture 1:2. The *P. contorta* are about 25 to 30 feet high and are rather rough specimens. Alongside is a small area planted at the same time using a provenance from Quesnel (Northern Interior British Columbia). This is only about 18 feet tall and very sparsely branched, contrasting strongly with the heavy, dark green branches of the coastal type.

THE EFFECT OF SITE AND SPACING ON GROWTH AND FORM

One could not help being impressed by the variability in growth form particularly of South Coastal *P. contorta* on different ground types, at different spacings and under differing conditions of exposure. On the richer soil types, such as the

deep meadow loam soils at Avondale, County Wicklow, it showed up very poorly in comparison with other species such as *P. radiata*. The latter would, however, doubtless fail at an elevation of 1,400 feet in full exposure, on the crest of one of the Wicklow Hills, where the same South Coastal *P. contorta* was growing quite vigorously.

On the poorest soil types such as Kilworth and Forth, the form was superior to that on the better ground at Ballinglen, County Wicklow, and Baronscourt Compartment 109. It develops its worst form where it has full room for growth and a moderately fertile soil.

The variation in growth of South Coastal *P. contorta* on different soil and at different spacing is so great that at Favor Royal, County Tyrone, two parts of one compartment there had always been considered as two varieties. One part of the crop, on a poor steep bank, closely spaced initially and only thinned once (though it is up to 50 feet in height), has a good form and light branching, and has always been demonstrated as the Inland form var. *murrayana*. The rest of the compartment, on a much better soil type, and, since it was planted in mixture with Scots pine (which it easily suppressed), much more open grown, is of the coarse heavy-crowned type which is the normal form for *open grown* South Coastal *P. contorta*. There is in fact no sharp boundary line, and my firm conclusion was that there was no doubt that both crops were of South Coastal origin and may well have been from the identical seed. (Records now show this surmise to be correct.) In Eire they stressed the difference in branch angle as a provenance character. I pointed out that even within a fairly uniform Coastal crop great differences are apparent both in branch angle and heaviness of branching. Altogether I am inclined to think that this is more of an individual tree character or a reflection of spacing than a provenance one.

Evidence from our own provenance experiments points to a fairly close similarity between all Washington and Oregon coast collections, but from what I saw in Ireland it would be quite logical to conclude (in the absence of precise information of origin) that some of the worst stands with coarse branches and bad form came from seed off the true scrubby 'Shore Pine' whereas the seed from the stands of good form and fine branches came from within forest areas of good growth, but still near the coast. This theory could best be disproved if it could be shown that stands of good and bad form were of the same identity number; without better records this seems unlikely. Some of the older stands in Northern Ireland which had poor form also had exceptionally thick and unusually *fissured* bark, more like that of a Corsican pine.

With the Northern Interior and Rainer Forest types there seems to be less variation in form. This appears to depend more upon exposure with these types than with anything else, and takes the form of greater bushiness and better needle retention on the lower branches in sheltered sites. All the crops of Rainer Forest type which I saw were planted at similar spacings and under fairly uniform conditions of site.

The intermediate character of the Rainer Forest origin suggests that here there is a provenance combining the vigour of the South Coastal type with the good

stem form of the North Interior type. There are possible vigour advantages in such a southern intermediate type as compared with the northern intermediate type from the Terrace region which attracted R. F. Wood (1955). Fortunately, we now have plants from Irish stands of Rainer Forest origin ready for planting in a provenance experiment, so that a comparison of its growth with known South Coastal provenances under uniform conditions will shortly be made. Although this type was seen growing on a poor soil type it was not in an exceptionally exposed position and it would be useful to know how it behaves in a combination of poor soil and great exposure. Some doubt as to its inherent vigour is shown by the figures given by O'Kelly (1952) where he records that at Kilworth in Compartments 49 and 50 (Rainer Forest origin) the height of dominants was 28 feet at 17 years, whereas in Compartment 26 (presumably South Coastal origin) 45 feet at 22 years, the respective girths being on average 14 inches and 24 inches. The form of Rainer Forest provenance is undoubtedly good, but when South Coastal provenances are planted at 4 feet by 4 feet they also produce crops of reasonable form, e.g. Baronscourt, Compartment 109.

As we know from British practice, planting methods have a considerable effect on subsequent growth. Most of the early plantations were made by direct notching. Later turf and mound planting became the rule and more recently Cuthbertson ploughing on the peatlands and ploughing with, for instance, a R.L.R., on the tough heathland types has been fairly general. In Eire the labour position is such that a considerable amount of hand preparation is still done. At Forth Forest near Wexford I saw an area which had been planted in 1950 as an experiment. The *P. contorta* had been put into patches in which the soil had been loosened with a pick, but growth on this very infertile soil was poor and this was one of the few places where I saw coastal *P. contorta* in semi-check. I could not help concluding that if the area had been ploughed with the Scottish tine-plough (which is unknown in Ireland) the crop would by now be thriving. Where the soil was somewhat better the plants were doing quite well, particularly in the section of the experiment which had received a phosphate dressing.

SUSCEPTIBILITY TO PINE SAWFLY (*DIPRION PINI*, L.) ATTACK

Attack by the Pine sawfly had occurred at three of the forests I visited—Gortnamoyagh in Londonderry, Pettigo in Sligo, and Forth in Wexford.

At Gortnamoyagh the sawfly attacked a mixed crop of *P. contorta* and Sitka spruce planted in 1938. The former was of mixed origin and the attack was strikingly more serious on the North Interior type trees. Coastal type trees were attacked, but to a lesser extent. Since the latter were more vigorous, one could not say whether the insects preferred the less vigorous trees or whether the Inland type as such was selected. The attack was worst in 1953, and in this year some caterpillars began to attack the Sitka when the supply of *P. contorta* needles ran short. Some pine are dead and the Sitka still look thin in the foliage as a result (see Fig. 2).

At Pettigo the 1953 attack was also the worst. Pettigo is a forest largely on blanket bog and there is a very large area of *P. contorta*. The local staff were quite

emphatic that the attack was worse on the Northern Interior type trees, and though the South Coastal ones were eaten they recovered more rapidly whereas, unless there is a cataclysmic drop in the sawfly population, many of the Inland type stands will utterly fail (see Fig. 1). Control measures by hand-spraying had proved ineffective.

The attack of sawfly at Forth was on crops planted 1935. Here, exposure was a complicating factor, but if this is ruled out there is no doubt that as in the north the most severe attack was on the North Interior type and South Coastal plantations were completely free from attack.

MANAGEMENT OF MIXTURES

Some twenty-three different stands of mixtures incorporating *P. contorta* were seen. Of these, only four were in Eire, which tends to follow a policy different from that applied in Northern Ireland and Great Britain and which is described below.

The great majority of the mixtures seen were *P. contorta* in intimate mixture with Sitka spruce. A few were *P. contorta* mixed with Japanese larch or Scots pine. Two of those with larch look promising.

(a) *Mixtures in Eire*

At Pettigo, Inland *P. contorta* had been planted with Scots pine on deep peat, but both failed. At Forth, South Coastal type trees were planted around the edge of an 'Anderson' group with Sitka spruce, Scots pine, or Japanese larch (*Larix leptolepis*) within the group. (This spaced-group system has been described by Anderson, 1951.) The *P. contorta* rapidly suppressed all other species. On the sand dunes at Curracloe there is an accidental mixture which has resulted from beating-up of an area of Corsican pine with *P. contorta*. Both species are growing well and at about the same rate. Coastal type *P. contorta* was planted in groups or patches in a Sitka spruce crop at Ballyward, County Wicklow, in 1933. The soil is moderately fertile and as a result the *P. contorta* have topped the spruce by several feet, which has resulted in the pine becoming windblown by recent gales.

From what I saw myself in Eire and from discussions I had with Irish forest officers, I gathered that *P. contorta* and Sitka spruce mixtures were not used there on anything like the scale employed in Britain or Northern Ireland. Instead, the obvious tendency is to plant pure crops of such species as Sitka spruce down to a certain fertility limit, where there is a reasonable chance that a fair crop will result. When fertility drops below this limit, Coastal *P. contorta* is used as a pure pioneer crop, with the understanding that once a pioneer crop has been established, it will be followed in later rotations by more valuable species.

(b) *Mixtures in Northern Ireland*

1. Mixtures of Sitka spruce with North Interior type of *P. contorta* were seen at Gortnamoyagh, Cam, Springwell, Baronscourt, and Kesh, County

Fermanagh. The first of these had suffered sawfly attack and cannot therefore be considered as a normal crop.

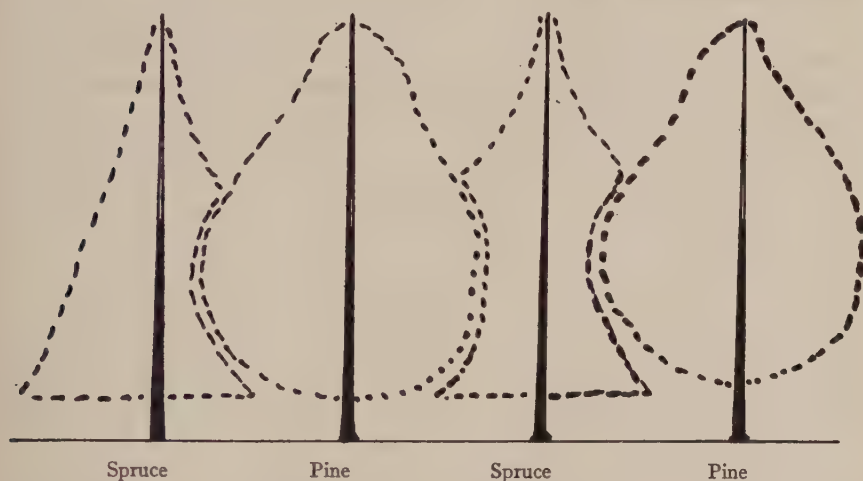
At Cam Forest, Compartment 81, the crop planted 18 years ago has still not closed canopy and the ground vegetation of *Calluna* with *Molinia* is still sufficiently dominant to keep the Sitka spruce in a semi-checked state, while the *P. contorta* is so sparsely foliated that it seems unlikely ever to be successful in killing out the *Calluna*. This is on a poor, deep peat, but where the ground type is appreciably better, as in Compartment 87 at Cam, while there is a chance of a reasonable mixture resulting, it is open to doubt whether pure Sitka spruce might not do equally well. In fact at Cam there is a pure crop of Sitka alongside the mixture and in both crops the Sitka is of approximately equal height. Only at Kesh, Compartment 6, did I see an example of genuine nursing by Inland *P. contorta*. Here there is no doubt that the pure Sitka spruce on the right of the road are much inferior to those in mixture on the left (see Fig. 4). Taken altogether, the dividing line between the ground type where Sitka will grow adequately pure and where it will be *gainfully nursed* by Inland *P. contorta* (i.e. not so bad as Cam Compartment 81) seems to be rather a fine one, and it demands a more accurate assessment of ground type and a greater knowledge of how the crop will grow than the great majority of us now possess.

2. Mixtures of Sitka spruce with South Coastal type *P. contorta* are proving difficult to manage. In the older crops the only really successful mixture of Coastal *P. contorta*/Sitka spruce is at Mullaghcrov (Baronscourt Compartment 201). Here the Sitka have kept up well with the *P. contorta* and are now only a few feet below them in height. In addition the Sitka have good clean straight stems and show a much superior windfirmness on this rocky site. The *P. contorta* have suffered damage from windblow which seems to be getting worse as the gaps increase with each gale. The original mixture must have been rather irregular here, and the ground type is such that the Sitka probably never suffered a serious check.

Even when the ratio of Sitka spruce/*P. contorta* is 3:1 the *P. contorta* are still dominant and, for instance, at Cam Forest Compartment 18, few Sitka spruce are visible in the upper canopy. The great difficulty in these mixtures lies in the terrific vigour of the coastal *P. contorta*, its absence of a check period in youth and the difference in crown form. Even if Sitka spruce in an intimate mixture does manage to keep up in height growth, the major volume of crown is below the crown mid-length point, whereas with the pyriform crown of the pine there is a bigger crown volume above the crown mid-length point (see diagram).

3. The difficulties of intimate mixtures of *P. contorta*/Sitka spruce are being tackled by vigorously cutting out *P. contorta* to free the spruce. To my mind this was being taken too far so that, e.g. at Springwell Compartment 27, where the mixture is two Sitka to one *P. contorta*, 50 per cent. of the 25 to 30 feet *P. contorta* are being cut out to free badly suppressed 4 to 5 feet Sitka. There is no doubt that the remaining *P. contorta* will continue to grow rapidly (unless they blow) whereas the Sitka cannot be expected to commence rapid growth

for a few years yet. By this time it will be necessary to cut back many more *P. contorta*. The alternative of letting the *P. contorta* come on as the main crop,



and favouring the odd Sitka spruce which shows reasonable growth, is disliked because the former (because of their early open growth) have a poor form and heavy branches. It must be admitted that there are occasional successes, but on balance I could not help concluding that on these difficult areas one must either grow *P. contorta* with Sitka in bands or else (and I incline towards this view) grow pure *P. contorta* as a pioneer crop to produce small size timber or pulp-wood, followed by clear felling or strip felling and replanting with a more valuable species.

THINNING OF OLDER PURE CROPS

The general trend of silvicultural thought amongst Irish foresters is that *P. contorta* must be heavily thinned, especially in the first two or three thinnings. The reason for this is caused partly by the swing of the pendulum towards heavy thinning in general, partly because it is appreciated that *P. contorta* grows very fast, and to a minor extent it may be due to the natural tendency for a forester to remove ill-shaped and coarse-branched trees from the crop. Crops of South Coastal *P. contorta* very often have a high proportion of poor stems. A crop of this type at Rathdrum forest Compartment 4, which has a top height of about 33 feet, has already been thinned twice. However, at Kilworth, where the Rainer Forest crop has excellent form, I saw a third thinning being carried out in a crop only 22 years old. Before the last thinning there were 1,030 stems per acre and the third thinning reduced this to 680 stems. It was mentioned that they would consider thinning in this type so heavily that high pruning of green branches would be necessary, but high pruning has more justification where labour is cheaper. It was acknowledged that high pruning on trees of unknown final timber quality was a risk.

WINDBLOW

Few of the older stands of South Coastal *P. contorta* which I saw had not suffered some degree of windblow and there seems little doubt that damage from wind must influence the rotation used with this species. It is one of the major problems now exercising the minds of those in charge of the forests on the blanket bog areas in the west of Ireland. Early thinnings have so far not produced wholesale windblows, but very often drainside trees are blown, leaving gaps in the canopy, and the suggestion was put to me that it might be necessary to grow crops on a pulpwood rotation without any thinning at all. As yet those Irish stands on deep peat are hardly tall enough to give us much information on effect of thinning treatment on windblow.

ACKNOWLEDGEMENT

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LORD CLINTON

LORD CLINTON, who died on 5th July at the age of 94, made an outstanding contribution to forest development in Britain. He inherited the Bicton estate in Devon and Fettercairn in Scotland in 1904, and in 1907 the much larger Torrington estate in North Devon; and he managed these properties with a competence which is reminiscent of the great eighteenth-century pioneers. Forestry was his special care and he loved to work in the woods.

He was naturally selected as one of the original Forestry Commissioners in 1919 and in 1927 he followed Lord Lovat as Chairman, an office he held until 1930. Earlier than this—in 1924—he became Chairman of the Lawes Agricultural Trust Committee, the governing body of the Rothamsted Experimental Station, and, as recorded by Sir John Russell in a recent letter to *The Times*, he guided the policy of this Station through eventful years.

My personal connexion with Lord Clinton started in the early thirties during the rather protracted negotiations with landowners from all over England which led to the formation of the Home Grown Timber Marketing Association. He initiated these proceedings and became the first President of the Association and so can justly be claimed as the founder of co-operative forestry in England.

Forestry Societies have many times been welcomed by Lord Clinton in his woods at Bicton, where there is a remarkable collection of large conifers, and at Torrington. We foresters looked to him as a great leader in our profession.

W. E. H.

DAMAGE CAUSED BY SQUIRRELS IN FORESTRY COMMISSION AREAS, 1954-6

By MONICA SHORTEN (MRS. VIZOSO)

(Infestation Control Division, Ministry of Agriculture, Fisheries, and Food)

SUMMARY

The paper examines the replies received from foresters of the Forestry Commission to questionnaires sent out at the author's suggestion in 1954, 1955, and 1956 on the damage caused to Forestry Commission woodlands by the two squirrels, *Sciurus carolinensis* and *S. vulgaris leucourus*, during the forest years 1954-6. The inquiry was primarily concerned with *S. carolinensis*, the grey squirrel, for the killing of which rewards have been offered since 1953, but, for 1955 and 1956, information was sought also about the red squirrel. The most serious economic damage done by both squirrels is considered to be the stripping of bark from the stems of growing trees and it is this damage which is examined. The information received is sifted critically and the results summarized in thirteen tables and in two diagrams.

INTRODUCTION

THE American grey squirrel (*Sciurus carolinensis*) has for many years been recognized as a destructive animal in the broadleaved woodlands of Britain. Growing concern has been caused as the range of the species has increased, and at the same time the expanding acreage of young broadleaved crops at the vulnerable pole stage has afforded greater risk of serious damage. In 1953 the Forestry Commission launched a bounty scheme, whereby a shilling was paid for the tail of every grey squirrel killed anywhere in England, Scotland, or Wales. Between March 1953 and the end of September 1955 nearly £33,000 was paid out. At the beginning of 1956 the reward was doubled, and has been continued at two shillings in 1957.

In order to gather more information on the distribution, type, and severity of damage caused by grey squirrels, and if possible to relate the total amount of damage with the numbers of tails collected, a questionnaire was devised at the suggestion of the author of this paper and accepted for circulation by the Forestry Commission to each of their forests, totalling approximately 500, in England, Scotland, and Wales. The questionnaires were answered by the forester in charge of each unit. The first, circulated in July 1954, sought for information on grey squirrels only and covered the forest year October 1953 to September 1954 inclusive. In 1955 questions were asked about both grey and red squirrels for the forest year 1955, and a similar questionnaire was circulated in 1956.

It is considered that the most serious type of damage done by either species of squirrel is the stripping of bark from the main stems of growing trees during the summer; and it is this form of damage which is examined in this paper.

METHODS

The 1954 questionnaire was divided into fourteen sections, asking for information on the following subjects: name of forest, county, and nearest town; total

acreage of woodland, and acreage of conifer, hardwood, and mixed woodland; main species present; whether grey squirrels absent, scarce, or numerous; whether damage to main stems absent, light, or severe; tree species attacked; type of crop attacked; whether damage occurred regularly in the summer, or in particular years only; acreage of each type of crop that was badly affected; number of trees per acre damaged so severely as to be rendered useless for main crop; availability of water to squirrels on the area throughout the summer; general observations; name and address of the forester completing the form, and the date. Answers were sought to cover happenings within the current forest year only.

For forest year 1955 two similar forms were sent to each forest, one to be completed for grey squirrels and one for red. Additional information sought was principally as follows: whether there were more or less squirrels than in 1954; whether damage was greater or less; which main tree species were present, with the age range for each; the tree species damaged: the total acreage of the crop, the acreage badly affected, the ages affected and the parts attacked.

Similar questionnaires were circulated in June 1956; again both for grey and red squirrels. Foresters were asked to give details of stock changes (clear felling, new planting, acquisitions or relinquished areas) and were reminded that information was sought only for the period since the last return had been made.

For the first two years the results were transferred to a card index; but in 1956 a punchcard system was devised to allow rapid analysis and cross-checking.

The total number of forest units covered each year varied. Apart from new acquisitions and areas relinquished, variation was caused by some large units which returned separate forms for a number of beats; so that totals quoted here for some Forest Conservancies, i.e. for main administrative units, do not agree with those given in the Annual Report of the Forestry Commissioners for the year concerned. In 1954 about 95 per cent. of units listed in the Report were covered, in 1955 100 per cent., and in 1956 over 98 per cent. were covered. Areas on which there were as yet no crops were ignored.

It would have been valuable to obtain complete stock lists, under species, ages, and acreage, for all those forests where damage occurred. Together with the details supplied on the forms, this would have given a picture of the relative frequency of attacks on different species and age groups, and the proportion of each type of crop damaged severely each year, in these forests. However, in many cases crops were mixed and scattered in such a way that this could not be done.

The 'forest area' which has been chosen as the unit of comparison in the text figures and tables is so variable in extent and in stock that it is by no means ideal for the purpose. The tables in the appendix should be consulted for details of the acreages affected by damage and the amount of damage per acre.

RESULTS

1. *Damage by grey squirrels, 1954-6*

Table I summarizes statements on damage from ninety-three areas which sent in reports for each of the 3 years under review, and from which damage was reported at least once during this period. It will be seen that an apparent reduc-

tion in the numbers of squirrels present was linked with a distinct decrease in the number of reports of severe damage, and a less-marked reduction in the reports of light damage. For the sample considered, the total number of areas reporting damage fell by 28 per cent. in 1955, and a further 24 per cent. in 1956.

TABLE I. *Numbers of Squirrels and Instances of Damage on Ninety-three Areas*

	1954	1955	1956
Number of forests reporting:			
Squirrels numerous, damage severe	14	1	1
damage light	24	9	8
damage nil	1	1	0
Total	39	11	9
Number of forests reporting:			
Squirrels scarce, damage severe	9	4	0
damage light	37	44	26
damage nil	8	34	53
Total	54	82	79
Squirrels absent	0	0	5
Total forests with severe damage	23	5	1
light damage	61	53	34
Total	84	58	35
Total forests covered	93	93	93

The relative figures for reports of damage and the degree of abundance of squirrels in all forests covered each year are given under Forest Conservancies in Table II. Because of differences in the total number of forests covered, figures are expressed as percentages of the total to allow comparison. Grey squirrels were absent from more than 50 per cent. of the forests covered, in all years. Where they were present, light damage was reported from 19 per cent. to 30 per cent. of the areas, and severe damage from 11 per cent. (1954), 2 per cent. (1955), and 0.4 per cent. (1956). The total number of forests in which some degree of damage by grey squirrels occurred was 87 out of 469 in 1954, 68 out of 538 in 1955, and 45 out of 551 in 1956.

Having obtained a general picture of the proportion of forest areas affected by squirrel damage in the 3 years under review, the next consideration is the relative frequency of damage to tree species and age groups, the parts of the trees usually attacked, and the time of year that the damage is done. Most foresters would agree that sycamore and beech are the most susceptible species, and that trees of between 15 and 40 years are usually singled out for attack. Damage is thought to occur mostly between late May and early August. Beech are said to be most often affected on the butts and the main stem just above the branches; whereas sycamore is often found to suffer damage in the crown.

In Table III the number of areas recording damage to a particular tree species

TABLE II. Grey Squirrels in Forestry Commission Forests: Damage Survey Results, 1954-6

Forest conservancy	Total no. forests '54 '55 '56	Squirrels absent (%) '54 '55 '56	Squirrels scarce (%) '54 '55 '56	Squirrels numerous (%) '54 '55 '56	Forests with squirrels '54 '55 '56	% with light damage '54 '55 '56	% with severe damage '54 '55 '56	Forests with damage '54 '55 '56
England (NE.).	40 42 46	50 62 57	43 36 43	7 2 0	20 16 20	15 19 10	15 0 0	6 3 2
(NW.)	35 35 38	51 57 61	49 43 37	0 0 3	17 15 15	6 13 27	12 0 0	3 2 4
(E.)	48 51 56	58 61 60	31 37 36	11 2 4	20 20 22	50 35 18	0 0 0	10 7 4
(SW.).	46 48 47	20 27 30	65 67 62	15 6 9	37 35 33	30 26 33	11 9 0	15 12 11
(SE.).	35 44 44	3 14 5	66 81 93	31 5 2	34 38 42	38 24 12	18 0 0	19 9 5
New Forest	3 13 15	67 15 33	0 54 60	33 31 7	1 11 10	100 55 30	0 0 0	1 6 3
Dean	13 13 13	0 0 0	54 100 100	46 0 0	13 13 13	69 69 15	31 0 0	13 9 2
ENGLAND	220 246 259	35 40 40	50 56 56	15 4 4	142 149 155	44 34 20	12 2 0	67 49 31
Wales (S.)	47 55 50	17 25 26	66 65 68	17 10 6	39 41 37	31 39 24	13 5 3	17 18 10
(N.)	34 35 43	44 60 53	49 31 37	7 9 9	19 14 20	0 7 10	0 0 0	0 1 2
WALES	81 90 93	28 39 39	59 52 54	13 9 8	58 55 57	21 31 19	9 4 2	17 19 12
Scotland (N.)	51 61 64	100 100 100	0 0 0	0 0 0	0 0 0			
(W.)	33 45 39	76 76 67	21 22 28	3 2 5	8 11 13	38 10 15	0 0 0	3 1 2
(S.)	41 42 42	100 100 98	0 0 2	0 0 0	0 0 1(?)	0 0 0	0 0 0	0 0 0
(E.)	43 54 54	88 96 94	12 4 6	0 0 0	5 2 3	0 0 0	0 0 0	0 0 0
SCOTLAND	168 202 199	92 94 91	7 6 8	1 1 1	13 13 17	23 8 12	0 0 0	3 1 2
TOTAL.	469 538 551	55 60 58	36 36 38	9 4 3	213 217 229	29 30 19	11 2 0.4	87 68 45

has been expressed as a percentage of the total number in which the species was said to be present, within the group of forests where squirrel damage occurred. Of the forests suffering damage, some were dropped from the sample because they did not list all the tree species present. Data from the first two years of the survey have been used for the table.

TABLE III. *The Relative Frequency of Damage for Various Tree Species*

Tree species	No. areas in which present	No. areas in which damaged		% areas with damage		Parts of tree usually affected
		1954	1955	1954	1955	
Sycamore (<i>Acer pseudo-platanus</i>) . . .	72	50	37	70	51	Crowns; sometimes butts.
Beech (<i>Fagus sylvatica</i>) . . .	96	44	41	46	43	Butts, main stem, roots.
Oak (<i>Quercus robur</i> , <i>Q. petraea</i>)	87	18	11	21	14	Upper stem, branches.
Birch (<i>Betula</i> spp.) . . .	60	9	7	15	12	Upper main stem.
Ash (<i>Fraxinus excelsior</i>) . .	68	7	11	10	16	Upper main stem.
Sweet chestnut (<i>Castanea sativa</i>)	47	4	2	9	4	Upper branches and stem.
Jap. larch (<i>Larix leptolepis</i>)	71	5	3	7	4	Upper half of main stem.
Scots pine (<i>Pinus sylvestris</i>)	83	5	2	6	2	Upper branches and stem.
Poplar (<i>Populus</i> spp.) . .	34	1	0	3	0	Tops.
Hornbeam (<i>Carpinus betulus</i>)	10	5	3	..	..	Tops.
Maple (<i>Acer platanoides</i> and spp.)	10	3	0	..	..	Tops.
Aspen (<i>Populus tremula</i>) . .	18	1	1	..	..	Crown.

Poles of Corsican and Maritime pine (*Pinus nigra* var. *calabrica*, *P. pinaster*) were reported to be damaged in one area in 1954; upper stems of young *P. contorta* in both years on one area; and branches of *Thuja plicata* and tops of *Tilia* spp. in 1955 on one area. There was also one report of damage to stems of *Robinia pseudacacia* transplants and to young *Prunus avium*.

The foregoing evidence supports the view that sycamore and beech suffer a higher proportion of attacks from grey squirrels than do any other tree species; oak, ash, and birch being attacked in only 10–20 per cent. of the forests where they occur and where damage of some kind is being done by grey squirrels. Other species were less commonly attacked. Some, listed as present in only twenty areas or less, have not been used for percentage figures in Table III.

It is interesting to find that several coniferous species were reported to be damaged by grey squirrels. These trees are attacked by red squirrels, but are often assumed to be immune from damage caused by the other species. In 1954 Corsican pine was reported to have been damaged at Hensol, and the following year red squirrels were said to be absent there; Maritime pine was said to have been attacked at Purbeck in 1954, and there again red squirrels were reported absent the following year. *Pinus contorta* was listed as damaged at Brecon in both 1954 and 1955, and this was attributed to grey squirrels, although red squirrels were present but scarce in 1955. At Dymock in 1955 *Thuja* was said to have suffered

damage in the absence of red squirrels; the same year, Japanese larch was reported to have been attacked at Brechfa 2 and 4, and at Llanover—red squirrels being numerous at the first two forests but absent at Llanover (none having been seen for at least four years). Scots pine was also damaged at Llanover that year, and at York, where red squirrels were said to be absent. In 1956 Scots pine were damaged at Cleveland, in the absence of red squirrels; and Japanese larch and Scots pine were again damaged at Llanover. Damage to Scots pine at Cyrchan was attributed to grey squirrels although red squirrels were present but scarce.

In Fig. 1 an attempt has been made to show the most susceptible age range for each of the tree species commonly attacked. Only those forests having damage to some crop in 1955 were used to provide the figures for age groups present/attacked. Sycamore of all groups from 0 to 60+ years, and beech from 11 to 40 years, were reported as damaged in 50 per cent. or more of the areas where they were present. Oak between 21–30 years of age was damaged in 26 per cent. of the forests where it was present.

Tree species less commonly reported as attacked are listed in Table IV together with the ages at which they were affected. Records for 1954 and 1955 have been used here.

TABLE IV. *Tree Species Reported as Damaged by Grey Squirrels, but Infrequently*

Species		Ages attacked	
Scots pine		0–25, 15–17, 20–40, 34, poles	
Hornbeam		0–40, 10, 10–20, 20–30, 30–70	
Maple		0–25, 18–20	
Aspen		0–24, 15–25	
Poplar		25	
Corsican pine		0–25, 23	
Maritime pine		Poles	
Gean		Trees 8–18 in. high	
<i>Tbuja</i>		20–80	
Lime		0–60	
False acacia		Transplants	
<i>Pinus contorta</i>		20–40	
Japanese larch		11, 15, 15–18, 18	

Reports showed that damage most often occurs during May, June, and July. In 1954 foresters were asked to comment upon the regularity of attacks. Of 32 forests where squirrels were said to be scarce, 16 reported regular damage occurring from late spring to early autumn; 3 reported sporadic damage (one linking damage with dry seasons); and 13 reported damage as occurring in particular years only. Of forests where squirrels were said to be numerous, 10 reported regular summer damage (one stating that damage was more marked in dry summers); one reported sporadic damage, one stated that damage was noticed for the first time 18 months before, and one gave the winter of 1952 as the only time that damage had been found.

The type of damage which is considered in this report involves the stripping of bark from main stems of trees during the summer months. It is thought that

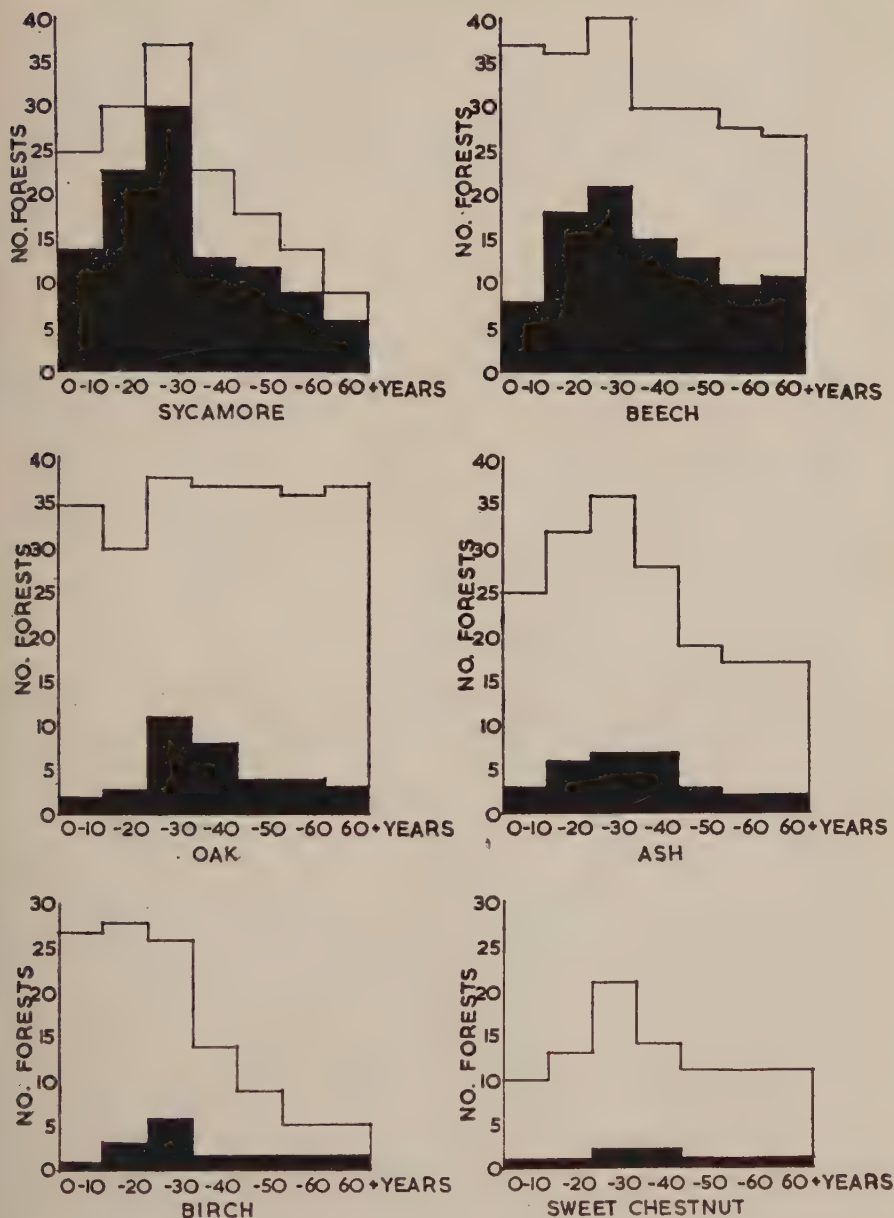


FIG. 1. Tree species most frequently damaged by grey squirrels arranged to show the number of forests having each age group present/attacked among those suffering damage to some species in 1955. The age group present is shown in white, the age group attacked is shown in black.

squirrels do this to obtain the sap from the cambium layer. Shreds of bark are left at the foot of the tree, and this provides a means of distinguishing between damage done by rabbits and by squirrels on butts. Where damage is done to the upper parts of the tree, it is usually found on the main stem just above a branch fork. If the cambium of the main stem is girdled between the ground and the lower branches the tree may die as a result; if cambium is removed from higher up the stem, then the parts of the tree above the gnawed ring may die and the growth of the laterals will increase, producing a deformed tree. Squirrels do not always ring a stem completely in one season; but the following year new damage may start round the scars of the previous season.

It is not known whether the chief attraction of the cambium for squirrels lies in the water content of the sap or in the sugars and salts present. Although some foresters were of the opinion that damage was worse during dry seasons, or in places where water was not available to the squirrels throughout the summer, there were at least four cases of damage occurring near streams of water.

Descriptions of damage are given in the appendix. In 1954 some 4,000 acres at least were affected, and in 1955 a minimum of 2,600 acres; in 1956 between 600-700 acres were listed as attacked, but scattered damage also occurred over wide areas. These estimates are necessarily rough approximations.

2. Damage by red squirrels in 1955 and 1956

The fact that the red squirrel (*S. vulgaris leucourus*) can become a serious pest in forest areas tends to be overlooked now that the species is relatively scarce. Accounts of damage done to young Scots pine can be found in the literature of the past 150 years; and damage to plantations of larch and spruce has also been recorded.

Table V summarizes reports of the abundance of red squirrels in forests during 1955 and 1956, and the damage caused by them. In every case but one, conifers were attacked (the exception being damage to 4-year-old beech at Glynn Tarell in 1956). Scots pine was most commonly attacked; *Pinus contorta*, Norway spruce (*Picea abies*), and European larch (*Larix decidua*) were less often affected. The ages attacked ranged between 0-40 years, with exceptions at Strathnairn (65 years) and Faskally (20-60 years). The relative frequency of attacks on the various species present where damage occurred in 1955 is shown diagrammatically in Fig. 2.

Red squirrels strip bark from the upper half of the main stem, often from the top 10 feet. Possibly such damage is more easily overlooked in conifer plantations than is damage to butts and main stems of hardwood species; sometimes the first indication may come many months after the attack when plantations are being thinned, or when the tops are blown out by the wind. May, June, and July appear to be the months when most damage is done.

The abundance of red squirrels in 1956 was compared with that of 1955 on 85 forest areas. A reduction was reported in 54 instances, and an increase in 31 instances.

Damage done during 1955 and 1956 is tabulated in the appendix.

TABLE V. *Abundance of Red Squirrels and Damage Caused by Them in 1955 and 1956*

Forest conservancy	Total no. forests		Squirrels absent (%)		Squirrels scarce (%)		Squirrels numerous (%)		Squirrels present		Damage light		Damage severe	
Year . .	'55	'56	'55	'56	'55	'56	'55	'56	'55	'56	'55	'56	'55	'56
England (NE.) .	42	46	52	57	48	41	..	2	20	20	..	..	..	..
(NW.) .	35	38	54	58	46	39	..	3	16	16	..	..	..	..
(E.) .	51	56	37	48	30	25	33	27	32	29	2	1	..	2
(SW.) .	48	47	62	68	38	32	..	..	18	15	..	..	..	..
(SE.) .	44	44	98	98	2	2	..	..	1	1	..	..	..	..
New Forest .	13	15	77	86	23	7	..	7	3	2	..	..	..	..
Dean . .	13	13	100	100	..	..	..	..	..	..	..	..	..	..
ENGLAND . .	246	259	63	68	30	25	7	7	90	83	2	1	..	2
Wales (S.) .	55	50	38	42	47	50	15	8	34	29	2	2	..	..
(N.) .	35	43	6	7	77	72	14	21	33	40	1	..	1	..
WALES . .	90	93	25	26	59	60	16	14	67	69	3	2	1	..
Scotland (N.) .	61	64	62	58	38	42	..	..	23	27	3	2	..	..
(W.) .	45	39	31	31	67	69	2	..	31	27	1	1	..	..
(S.) .	42	42	41	48	57	48	2	4	25	22	..	1	..	..
(E.) .	54	54	22	22	76	74	2	4	42	42	3	4	..	..
SCOTLAND .	202	199	40	41	59	57	1	2	121	118	7	8	..	..
TOTAL . .	538	551	49	51	45	43	6	6	278	270	12	11	1	2

DISCUSSION

1955 was undoubtedly a poor year for grey squirrels. A reduction in their numbers was noticed in many forests: of 150 areas which compared numbers present with those of the previous year, 96 reported a decrease, 35 reported no change, and 19 said there had been an increase (15 of the latter being in Wales and south-west England). Fifty-one forests for which the degree of damage in 1955 was compared with that in 1954 reported less damage in 38 cases, no change in 7 cases, and greater damage in 6 cases (all the latter group being in south Wales and southern England).

Corroborative evidence of this apparent reduction in numbers came from the County Agricultural Executive Committees whose recorded kills, calculated from the number of tails handed in to pests officers, were low in comparison with those of the previous year. In the first quarter they represented 81 per cent. of those received in the same quarter of 1954: in the second quarter 33 per cent., and in the third quarter 28 per cent. (Figures for the last quarter were not compared because the bounty was about to be increased, and tails were probably withheld because of this knowledge.) All counties of England and Wales were included in these comparisons; and it was found that six Welsh counties and eleven English counties had higher kills in the first quarter of 1955 than they did in the same quarter of 1954, but the second quarter showed only two Welsh and two English

counties with comparatively higher kills and the third quarter showed none at all with higher kills. The forest years run from the 1st of October to the end of September, so that in some districts no decrease in numbers of grey squirrels may have been apparent until the second half of the forest year. The reduction would,

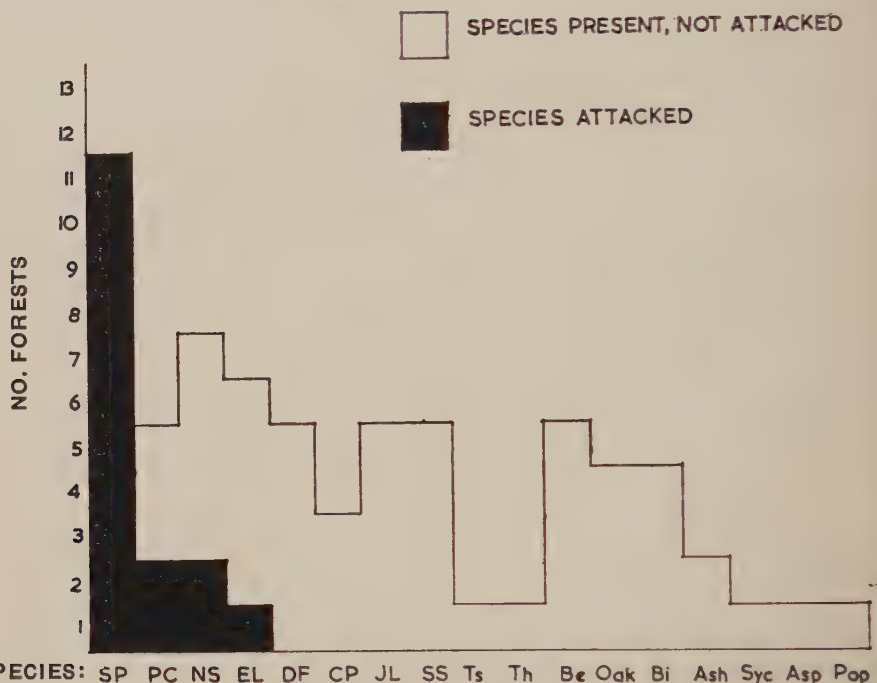


FIG. 2. Tree species present/attacked in thirteen forests which reported damage by red squirrels in 1955. SP = Scots pine; PC = *Pinus contorta*; NS = Norway spruce; EL = European larch; DF = Douglas fir; CP = Corsican pine; JL = Japanese larch; SS = Sitka spruce; Ts = *Tsuga heterophylla*; Th = *Tbujia plicata*; Be = Beech; Bi = Birch.

however, have been general and marked by the time that damage started in late May.

During the period September 1955 to August 1956 (inclusive) the decrease in numbers of grey squirrels on Forestry Commission areas appears to have continued. Of 140 forest areas reporting some change in numbers, 122 reported a reduction and 18 reported an increase. Figures for the numbers of tails handed in cannot be used to corroborate this since the award had been increased.

The figures in Table I suggest that cases of severe damage were appreciably reduced in 1955, but that the number of instances of light damage was not very different. Some doubt is thrown on the validity of this table by the details of damage given by the foresters and listed in the appendix (Tables VI–XIII). It appears that different conceptions were held as to the distinction between 'light' and 'severe' damage. If the survey can be continued over a number of years, and if the majority of the areas continue to have the same foresters meanwhile, then the comparative results will be of more value.

To justify classification as 'severe', it is considered that damage should in some way affect the final value of a productive crop to an appreciable extent. Scrub, amenity trees, trees in devastated woodland, trees marked for thinning, or isolated trees of small importance may be severely attacked without necessarily warranting the classification 'severe' to describe damage on the area.

No attempt has been made to calculate the financial loss represented by squirrel damage on Commission land during the years under review; it is questionable whether any such calculation could be accurate. No attempt was made to survey damage on private woodland throughout the country.

It would be interesting to investigate the effect of providing solutions, containing the most important sugars and salts found in the sap, at places where damage is anticipated. So far as is known, no such experiment has been attempted; but it has been shown that red squirrels can be lured into traps containing no bait other than water, during the dry season.

Damage by grey squirrels to oak appears to be mainly restricted to South Wales and south-west England; in 1955 cases were reported from the Forest of Dean (4), South Wales (3), south-west England (3), the New Forest (2), and south-east England (1).

It is surprising to discover that in America the grey squirrel is rarely accused of damage to forest crops. Hans G. Uhlig, of the Conservation Commission of West Virginia, states in a personal communication that the attitude of the Forest Service towards grey squirrels is favourable, perhaps because 20 per cent. of the licence fee charged to hunters goes to the Service. He is of the opinion that not one tree in 10,000 is damaged to the extent that it is killed by girdling. Yet in this state 64 per cent. of the land area is forested, 55 per cent. of the forests are pole timber stands, and although between 750,000 and 1,500,000 squirrels are killed annually for sport, this is said to represent only 13 per cent. of the total population of grey squirrels. The five most important types of forest are red oak (*Quercus rubra*); yellow poplar (*Liriodendron tulipifera*); sugar maple (*Acer saccharum*) with beech (*Fagus americana*) and yellow birch (*Betula lutea*); chestnut oak (*Quercus prinus*); and white oak (*Q. alba*). Sycamore is said to be 'unimportant'.

CONCLUSIONS

1. The most important type of squirrel damage, economically, is the stripping of bark from the main stems of young trees. This occurs typically in the months of May, June, and July. As a result, trees may be deformed and sometimes killed.

2. At present, damage by grey squirrels is more widespread and more severe than damage by red squirrels. Grey squirrels most commonly attack hardwoods, but may also damage conifers; red squirrels rarely if ever attack hardwoods. The species most often damaged by red squirrels is the Scots pine, between 0 and 40 years of age. Grey squirrels appear to attack sycamore most frequently, from 0 to 60+ years of age. Beech is damaged slightly less frequently, most often between the ages of 10 and 50 years; and more rarely oak, birch, and ash are damaged. A number of other species, both broadleaved and coniferous, are sometimes affected.

3. Reports of severe damage by grey squirrels were as follows: 1954, 24; 1955, 5; 1956, 1. Reports of light damage were: 1954, 63; 1955, 64; 1956, 44. More than half the forests reported grey squirrels to be absent each year.

4. Reports of severe damage by red squirrels were: 1955, 1; 1956, 2; and reports of light damage were: 1955, 12; 1956, 11. Red squirrels were said to be absent from 49 per cent. of all forests in 1955, and from 51 per cent. in 1956.

5. It is hoped that the information presented here may be useful to those foresters with crops of susceptible species, nearing the most vulnerable age range. It is difficult to estimate the relative importance of squirrel damage compared with losses due to insect pests, other woodland animals, disease, and fire hazards; or to calculate any percentage loss on the Forestry Commission's yearly turnover due to this single cause; yet it is clear that in particular areas squirrels can cause appreciable damage.

ACKNOWLEDGEMENTS

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APPENDIX

Detailed information on damage caused by grey squirrels in 1954, 1955, and 1956; and by red squirrels in 1955 and 1956, is given in Tables VI-XIII below.

The principal abbreviations used for species in the Appendix are as below:

SP = Scots pine	CP = Corsican pine	Th. = <i>Thuja plicata</i>
PC = <i>Pinus contorta</i>	JL = Japanese larch	Be. = Beech
NS = Norway spruce	SS = Sitka spruce	Bi. = Birch
EL = European larch	Ts. = <i>Tsuga heterophylla</i>	Hb. = Hornbeam
DF = Douglas fir	MP = Maritime pine	

TABLE VI A. *Damage by Grey Squirrels, 1954.*
Classed as 'Severe' by Foresters (24 forests)

<i>Forest Conser- vancy</i>	<i>Forest</i>	<i>Spp. attacked, and ages</i>	<i>Acres damaged</i>	<i>Trees per acre badly damaged</i>	<i>Trees per acre useless</i>
England	Jervaulx	Syc. (no ages given)	3	100	75
	Byland (Am- pleforth)	Syc. 10-15 yrs.	50	33 %	(not main crop)
	Sand Hutton (York)	Syc. 0-40 yrs.	3	150	50
	(NW.) Swynnerton	Syc. 10 yrs.	5	60%	60 %
	Mortimer	Syc. 20-30 yrs.	groups	10-15 % (groups)	10-15 % (groups)
	(SW.) Stokeleigh	Syc. 20-40 yrs. Be. 20-30: -70 yrs. }	70	{ 2 20	c. 10 (10:1 mixture with other spp.)
	Bruton	Syc. (no ages)	20	all	80 %
		Be. (no ages)	15	all	
		Oak (no ages)	4	all	
	Stanway	Syc. coppice	4	..	..
	Cowley	Be., Syc., JL (no ages)	20	..	..
	(SE.) Brightling	Hb. coppice	..	..	..
	Effingham	Syc. coppice, Hb. }	320	..	devastated
		Be. 80-100		..	
	Shere Manor*	Syc. 0-60	4	5,500	..
		Be. 10+	28	2,250	..
	Q. Elizabeth	Be. 24 yrs.	1,700	6-8	2
		Maple 18-20 yrs.	..	..	..
	Hursley	Syc. 25 yrs.	17.5	120	70 %
		Be. 40 yrs.	12.7		
Forest of Dean	Alton	Syc., Be., Bi.	scrub	1.2	..
	Tidenham	Syc. 10-60 yrs.	16.5	3-4	..
	Chase	Be. 30-40 yrs., Bi., Oak	..	..	..
	Edgehills	Syc. 20-30 yrs.	374	..	..
	Highmeadow	Syc. 15-30 yrs.	1	400	250
		Be. 20 yrs.	7.5	360	190
		Oak 40 yrs.	15	220	140
		Be. 25 yrs.	7	25	10
		29 yrs.	4	30	15
Wales (S.)	Dean East	21 yrs.	10	20	5
		Oak 25 yrs.	6.5	35	12
		45 yrs.	24	20	5
		Tintern S.	52	80	60
		Chepstow	3-400	10 (all)	40-60
	Monmouth	Syc. 12 yrs.	..	80	50 % (ride-side and boundaries)
		Be. 25-30 yrs.	..	24	
		Oak 14-25 yrs.	..	36	
	Draethen	Syc. 20-30 yrs. (coppice)	odd trees	..	..
	Brechfa 4	JL 11 yrs.	22	6 in all	6 in all

* Some damage done in previous years included.

TABLE VI B. *Damage Listed as 'Light' by Foresters in 1954: but which appears to have been Severe when Details are Considered (21)*

<i>Forest Conser- vancy</i>	<i>Forest</i>	<i>Spp. attacked and ages</i>	<i>Acreage damaged</i>	<i>Trees per acre badly damaged</i>	<i>Trees per acre useless</i>
England (NE.) (E.) (SW.) (SE.)	Cleveland	Syc. 25 yrs.	10	100 (+ past yrs.)	100 (+ past yrs.)
	Ampleforth	Syc. 12 yrs.	20	5-10	..
	Salcey	Be. (no age)	20	50 %	20
	West Woods	Syc. 22 yrs.	2-3	300	300
	Dymock	Syc. 18-20 yrs.	5 (with EL)	500	500
		Oak 30-35 yrs.	4 (with JL)	40	40
	Bere	Be. 26-38 yrs.	('Cpt. 6')	..	..
		Oak 23 yrs.	('Creech')	40	40
	Chiddingfold	Oak 25-30 yrs. coppice	50 }	4	4
		Hb. 10-20 yrs. coppice	20 }		
	Slindon	Be. (no age)	30 x 1 ch.	100	10
	Arundel	Be. (no age)	75	..	40-50
		Syc., N. Mpl.	..	..	..
	New Forest	Syc.	..	20 %	thickly ptd.
New Forest Dean		Be.	3	10	1 %
	Nagshead	Syc. 18-24 yrs.	9	300	200
		Be. 30-36 yrs.	8	..	100
	Ross	Oak, Sw. Ch.	200	60	50
	Blakeney Hill	Be. 18-39 yrs.	15.5	90	50
	Dean South	Be. 28 yrs.	30	90	90
	(Slade)	Ash 28 yrs.	..	slight	..
	(Norebarn,	Oak (nat.)	..	25	..
	Bearse, Noxin)	Be. 26-39 yrs.	..	50	50
	Dean Centre	Be.	10	20	20
		Oak	4	30	30
	Crychan	Be. P 54	1	200	..
		SP (25 ft.)	..	10-15	..
		NS (15 ft.)	..	10	..
Wales(S.)	Brechfa 2	JL 18 yrs.	20-25	20-25	10-20
		SP 15 yrs.	0.5	40-50	35-40
	Talybont	Be. -16 yrs.	belts	..	100
		Syc. 15-35	2	1,000	700
	Llanover	JL (no age)	60	6	..
	Hay	Syc. 20-30 yrs.	10	10	..
		Oak	..	..	..
	Tintern	Syc. 23 yrs.	22	10	10
	Centre	Ash 23 yrs.	22	2	2
		Bi. 23 yrs.	5	1	1
		Sw. Ch. 23 yrs.	2	2	2

TABLE VII. *Forests Reporting Bad Damage to Small Numbers of Trees in 1954 (24).
Classed as 'Light' by Foresters*

Forest Conser- vancy	Forest	Spp. damaged and ages	Acreage damaged	Trees per acre badly damaged	Trees per acre useless
England					
(NE.)	York	Syc. all ages	none	2-3	2-3
(NW.)	Long Mynd	Syc.	none	2	rare
(E.)	Kesteven E.	Syc. 20 yrs.	none	20 % (low quality)	20 % poor
	Ampthill	Syc. 30, Sw. Ch. 30, Pop. 25 yrs.	..	5 (all)	2 (all)
	Bernwood	Oak, Aspen	100 (each)	sporadic	few
	Rockingham	SP 20 yrs.	none	very few	..
	Nassburgh	Oak (40 ft.); Ash coppice	none	sporadic	..
(SW.)	Sedgemoor	Syc. poles	none	very few	none
	Blandford	Syc., Maple, Coppice	none	odd trees	odd trees
	Charmouth	Syc. 25 yrs.	6.5 (with larch)	odd trees	none
	Gardiner	Oak 16 yrs.	none	c. 12 trees	none
	Savernake	Be., Syc., Bi.	none	odd trees	none
	Bradon	Be., Bi.	none	odd trees	none
(SE.)	Andover	Syc. 35 yrs.	6	3	none
	Rogate	Be. 20, Syc. 20 yrs.	small	50-60 %	50 %
	Westbury	Be. 20 yrs.	none	2-3	none
	Alice Holt	Syc. 20 yrs.	small	few	none
Dean	Cockshoot	Be. 20 yrs.	15	4-5 in all	none
	Serridge	Be., Oak	none	2	none
Wales	Hensol	CP 23 yrs.	5-8	none	..
(S.)	Caio	NS (10-15 ft.)	3	5 %	1 %
	Coed	..	..	..	..
	Caerdydd	Be., Syc.	6	none	none
Scotland	Lennox Castle	Syc. 25 yrs.	none	1	1
(W.)	Garadhban	Gean (8-18 in.)	1	none	none

In addition, 18 forests reported slight damage only (classed as 'light' by foresters) during 1954. Reports were as follows:

England (E.). *Bedford Purlieus*: scattered trees of nat. Syc.; some thinned. *Apethorpe*: Ash 40 ft., SP 34. None severe, but 50-75 trees p.a. affected, SP most frequently. *Kesteven W.* Scattered trees of Be., very light damage. *Wailington*: Be., Syc.

England (SW.). *Shepton*: Odd trees of Be. (20-30 yrs.); none severe. *Purbeck*: Syc. saplings; Sw. Ch. 60-80 yrs.; poles of SP, MP. *Aconbury*: Ash.

England (SE.). *Bedgebury*: Hb, 20-30 yrs. Understory not main crop; odd stems on 470 a. *Cballock*: Bi. 15-20 ft.; damage negligible; unproductive trees (nat.). *Havant*: Scrub Syc. only damaged. *Marden*: Be. *Gravetye*: Be., Syc., Bi., Hb.

Dean. *Lea Bailey*: Syc. 30 yrs. Few attacked, none severely. *Dean West*: Be. 30-40 yrs. No severe damage.

Wales (S.) *Tintern N.*: Be., Syc., Oak. Ride-side or coppice. Not appreciable. *Brecon*: Be., JL, PC (20 yrs.); will be thinned. *Llantrisant*: Large Be., branches only damaged.

Scotland (W.) *Garelochhead*: Be. and Oak shelter belts.

TABLE VIII. *Illustrations of Severe Damage by Grey Squirrels in 1955*

Forest Con-servancy	Forest	Spp. and ages mainly attacked	Total acreage of crop	Acres damaged	Trees per acre badly damaged	Trees per acre useless
<i>A. Damage listed as 'severe' by foresters (5 forests)</i>						
E.(SW.)	Bradon	Syc. 10 yrs. Bi. 0-25 yrs.	Syc. 2 Bi. odd trees	Syc. 2 odd trees	all ..	all ..
	Bruton	Be., Syc., oak 20-80 yrs.	6	6	all	70%
	Aconbury	Sw. Ch., Be (20+) Syc., Ash 10+ yrs.	not known		25% of Sw. Ch. damaged in tops.	
Wales (S.)	Talybont	Be. 15 yrs. Syc. 30 yrs.	3 2	3 2	650 430	320 208
	Brechfa 4	Be. 15 yrs. JL 15 yrs. nat. Syc.	belt 50 ..	odd trees odd trees odd trees		
<i>B. Damage listed as 'light' by foresters, but which appears to have been severe when details are considered (13 forests)</i>						
New	Fritham	Be. 25-80 yrs.	500+		30-50	20
		Be. 80-200 yrs.		50	20-30	..
		Oak 25-40 yrs.)		2 stems	..	..
Dean	Highmeadow	Oak 0-34 yrs.	100	1	10	10
		Syc. 0-25 yrs.	20	3	50	50
		Be. 0-40 yrs.	..	slight	..	..
	Nagshead	Syc. 19-25 yrs.	not known	2.9	50	40
		Be. 19-38 yrs.		6.5	35	30
Wales (S.)	Coed	Be. 0-5 yrs.	12	2	100	none
	Caerdydd	Syc., Ash 15-20 yrs.	..	odd trees	..	..
E.(E.)	Salcey	Be. P. 15	35	35	60	40
	Watlington	Be. 100-50 yrs. Syc. 20 yrs.	350 1	5 0.5	50 100	none 50
E.(NE.)	Sand Hutton (York)	Syc. 0-40 yrs.	3	3	150	50
E.(SW.)	Haldon	Syc. 20-80 yrs.	20	20	1,000	800
	Dymock	Oak 20-80 yrs.	250	5	10-12	75%
E.(SE.)		Syc. 0-25 yrs.	3	3	400/500	75%
		Th. 20-80 yrs.	1	..	20-30	..
	Marden	Be. 1-5 yrs.	17	11	450 (30%)	too early
		Be. 28 yrs.	6	6	400 (80%)	200
	Westbury	Be. 24-26 yrs.	365	odd trees	4-5	4-5
	Q. Elizabeth	Be. 16-26 yrs.	1,700	1,700	4-5	4-5
	Shere Manor*	Be. (pure crop) 10+	40	40	2,500 (99%)	1,300 (50%)
		Be. (mixed)	70	20	30 (1%)	..
		Be. (old wood-land)	500	500 (sl.)	60-70 (60%)	..

* Some damage done in previous years included.

The remaining forests which suffered from damage in 1955 have been divided into two groups: those which reported severe damage to low numbers of trees, and those in which only light damage was reported. The species of trees mainly affected are given; but rarer instances have been omitted.

TABLE IX. *Twenty Forests Reporting Severe Damage to Smaller Numbers of Trees (1955)*

Conservancy	Forest	Damage reported for 1955
England (NW.)	Mortimer	Be., Syc., 1 % p.a. rendered useless for maincrop.
England (SW.)	Haugh	Be. (damage negligible); oak coppice in 20 a. EL pltn. damaged.
	Stokeleigh	Be., 1-2 p.a. damaged, 1 p.a. useless as result; Syc., damage less frequent than to beech.
	Moccas	Ash, 1-2 % p.a. severely damaged.
England (SE.)	Arundel	Syc., Bi., odd trees damaged, none useless as result.
	Bere	Be., odd trees damaged over 14 a.; Oak, 4-5 trees p.a. damaged over 19 a.; 4 p.a. useless.
	Effingham	Be., Syc., Ash, scattered trees damaged.
	Crawley	Be., 7 trees p.a. damaged over 4 a.; will be thinned.
New Forest	Holmsley	Be., on 2 out of 53 a., 5 % p.a. damaged, 1 % p.a. useless.
Dean Forest	Tidenham	Be., Syc., Oak, Bi., 1-5 p.a. severely damaged; less than 1 % p.a. rendered useless.
	Chase	
	Edgehills	Be., 1 tree damaged on 9 a.; Syc., 1 tree.
Wales (S.)	Tintern N.	Be., odd trees in 3 ch. double row severely damaged; Syc., odd trees throughout belt of under 1 a.
	Tintern C.	Syc. (22 a.), Sw. Ch. (22 a.), Ash (2 a.), scattered trees severely damaged; 20-30 p.a. rendered useless.
	Brechfa 2	JL, 10 trees p.a. severely damaged on 38/750 a.
	Llanover	Be., JL, Sp, odd trees (4 p.a.) severely damaged.
	Chepstow	Syc., Oak, Ash, Bi., odd trees damaged in coppice; will be cleared and replanted.
	Tair Onen	<i>Robinia pseudacacia</i> , 12 trees on 1/4 a. severely damaged.
	Llantrisant	Be., 12 trees in all.
Wales (N.)	Coed Penllyn	Be. (P. 54), 200 trees damaged, 40 useless on 1/17 a.
Scotland (W.)	Lennox Castle	Syc. (nat.), a few scattered trees severely damaged.

TABLE X. *Thirty Forests Reporting Slight Damage Only (1955)*

<i>Conservancy</i>	<i>Forest</i>	<i>Spp. attacked</i>	<i>Remarks</i>
England (NE.)	Byland	Syc.	..
	York	Syc., Ash, SP	..
England (NW.)	Long Mynd	Syc.	..
England (E.)	Bernwood	Aspen	..
	Bedford	Syc. (nat., coppice)	..
	Purlieus	..	..
	Kesteven E.	Syc., Ash	..
	Ampthill	Syc., Ash, Sw. Ch.	No concentrated damage.
England (SW.)	Wendover	Be., Syc.	..
	Mendip	Be.	1½ a./45; 2 trees p.a. slightly damaged, none useless.
	Savernake	Be., Syc., Bi., Hb.	Negligible damage to old woodland.
	Blandford	Syc.	Odd trees.
	Cowley	Syc.	A few scrub trees attacked.
England (SE.)	Hursley	Be., Syc.	..
New Forest	Hurn	Oak, Bi. SP	Damage of no consequence.
	Lyndhurst	Be.	..
	Parkhill	Be., Syc.	..
	Stockley	Be., Syc.	Odd trees damaged, none severely.
	Lea Bailey	Be.	Odd trees on 20 a.; not severe.
Dean Forest	Cockshoot	Oak	Very light.
	Dean East	Be., Oak	Few trees, none severely damaged.
	Dean West	Be.	None severely damaged.
	Dean South	Be.	None severely damaged.
Wales (S.)	Nethergwent	Bi.	Odd trees on 352 a., none bad.
	Draethen	Syc.	Isolated occurrence.
	Tintern S.	Be., Syc., Oak, Ash, Bi.	None severely damaged.
	Glasfynydd	Syc.	Only 3-4 trees p.a. present.
	Mynydd-ddu	Be., Syc.	Odd trees; 3-4 p.a. present.
	Hay	Syc., Oak	Several trees damaged, none badly.
	Brecon	PC	Less than 1 % p.a. slightly damaged.
	Crychan	Be. (P. 54)	Odd trees on 2 a.; recovering.

TABLE XI. *Damage Caused by Grey Squirrels, 1956*

Forest Conservancy and forest		<i>Sp. and ages attacked</i>	<i>Acres attacked/ present</i>	<i>Trees per acre attacked</i>	<i>Trees per acre useless</i>	<i>Parts attacked: comments</i>
(a) <i>Grey squirrels numerous</i>						
E.(NW.)	Foremarke (Derby)	No details	..	..	..	Damage light.
E.(E.)	Salcey (Bucks., Northants.)	Be. 17 yrs.	2/2	40	20	Boles.
	Whaddon Chase (Bucks.)	Ash 15-20 yr. coppice	odd trees/ 124 acres ash/oak	very few	..	Main stem, 4-5 ft. from ground. Semi-derelict, due for felling and replanting.
E.(SW.)	Cowley (Glos.)	Syc. 20 yr. coppice	odd trees/ 3-4 acres	odd trees	all att.	Upper 10 ft.
	Haldon (Devon)	Syc. 20-80 yrs.	20/20	1,000	800	Crown.
	Stokeleigh (Som.)	Syc. 36 yrs.	4 trees/ 31.5 acres	..	..	Upper stem.
		Syc. 10 yrs.	3-4 trees/ 11.5 acres	..	..	Butt. Shelter trees only.
		Be. 40 yrs.	3-4 trees/ 50 acres	..	..	Butt.
W.(S.)	Glasfynydd (Brec.)	Syc. 60-80 yrs.	11/11	10 (visible)	..	Branches. Scrub, left for amenity.
		Be. 60-80 yrs.	11/11	4 (visible)	..	Branches.
	Coed Caerdydd (Glam.)	Be. 5 yrs.	odd trees/ 10 acres	..	..	Side shoots attacked (? grey squirrels).
	Tintern (Mon.)	Syc. 10-40 yrs.	odd trees/ groups	0.5 %	0.5 %	Leaders and laterals.
	(This damage was classified as 'severe'; and said to be linked with lack of water.)	Be. 20-60 yrs.	odd trees/ 20 acres	2 %	1 %	Leaders and laterals.
		Oak 15-30 yrs.	odd trees/ 50 acres	1 %	0.5 %	Leaders.
		Bi. 15-40 yrs.	odd trees/ groups	0.1 %	0.1 %	Leaders.
		Ash 10-40 yrs.	odd trees/ 15 acres	0.5 %	0.1 %	Leaders and laterals.
		Maple 20-50 yrs.	odd trees/ groups	0.1 %	0.1 %	Leaders.
		Elm 10-40 yrs.	odd trees/ groups	0.5 %	0.1 %	Mostly laterals.
		Alder 10-30 yrs.	odd trees/ groups	0.25 %	0.1 %	Leaders and laterals.
S.(W.)	Garadhban (Stirling)	Syc. 2 + 1	1/3.5	150	nil	Leader buds. Grey squirrels living nearby; after their destruction, damage ceased.
	Garelochhead (Dunb.)	Bi. 5-15 scrub	..	..	..	Crown and trunk. No app. damage on planted area.

TABLE XI (*continued*)

Forest Conservancy and forest		Spp. and ages attacked	Acres attacked/ present	Trees per acre attacked	Trees per acre useless	Parts attacked: comments
(b) Grey squirrels scarce						
E.(NE.)	Cleveland (Ingleby) Yorks.	SP 30 yrs.	1/2	20	nil	Lower crowns. No red squirrels.
	Ampleforth (Byland) Yorks.	Syc. 10-80 yrs.	odd trees/ 2,651 a.	neg.	neg.	3-5 in. diam. stems. Coppice.
		Be. 26 yrs.	odd trees/ 600 a.	less than 1	not crop	Be. suppressed under SP/larch. Stems 3-5 in. diam. att.
E.(NW.)	Walcot (Salop)	Syc.	Very occasionally		..	No details.
	Mortimer (Hereford)	Syc. 30 yrs.	odd trees, mixed with conifer	1 %	1 %	Tops.
	Long Mynd (Salop)	Syc. 35-50 yrs.	2/7	40	nil	Crown, branches. Coppice mixture with Ash, Elm, EL, DF, and Oak. Less than 1955.
E.(E.)	Wendover (Bucks.)	Be. P. 33	0.5/3.5	0.2	4	Butt 2 %, middle-top 10 %, top 2 %, top-bottom 6 %.
	Watlington	Be. 10-40 yrs.	30/300	5	nil	Root buttress.
		Wych elm 50-100 yrs.	odd trees/ hedges	..	..	Spring growth attacked.
E.(SW.)	Blandford (Dorset)	Syc. 35 yrs.	odd trees	..	..	Mainly tops. No details.
	Aconbury (Hereford)	Syc. 15-30 yrs.	odd trees	..	..	Upper branches. Uneven reserved area.
		Be. 15-30 yrs.	odd trees	Not assessable		..
E.(SW.)	Bruton (Som.)	Syc. 15-30 yrs.	4/4 mixed	70/all	70/all	Crown.
		Be. 50-80 yrs.	odd trees	..	..	Crown. All to be felled.
		Oak 20-50 yrs.	2/2 mixed	50	50/all	Crown.
	Dymock (Glos.)	Syc. 19 yrs.	5/5	10	10	Crown.
		Oak 26 yrs.	50/50	5	nil	Crown.
	Gardiner (Dorset)	Be. P. 39	odd trees/ 3 a./13	..	nil	Bole, 3 ft. from ground.
		Hazel coppice	1 stool	..	..	3ft ft. from ground.
	Moccas (Hereford)	No details	..	..	..	..
	Savernake (Wilts.)	Syc. and Bi.	odd trees/ total area	..	..	..
	Stanway (Glos.)	Syc. 15 yr. coppice	odd trees/ 117 a.	..	all attacked	Upper 5 ft. Actually beside small stream.
	Shere Manor (Surrey)	Syc. 10-40 yrs.	1/20	..	..	Stem, branches. Not a crop.
		Be. all ages	..	..	..	Root buttress, stem, branches.
E.(SE.)	Westbury (Hants)	Be. 20-24 yrs.	odd trees	..	..	Butts.
	Q. Elizabeth (Hants)	Syc. (old)	odd trees	..	..	Crown.
		Be. 20-30 yrs.	odd trees	..	50/all	Mainly butts.
	Marden (Sussex)	No details	..	..	..	..
	Bere (Hants)	Be. 50-55	..	21/all	..	Underplanted.

TABLE XI (continued)

Forest Conservancy and forest		<i>Sp. and ages attacked</i>	<i>Acres attacked/ present</i>	<i>Trees per acre attacked</i>	<i>Trees per acre useless</i>	<i>Parts attacked: comments</i>
(b) Grey squirrels scarce (cont.)						
New	Roe (Hants)	Be. 30 yrs.	odd trees	..	..	Main stem. No consequence.
	Fritham (Hants)	Be. 20-28 yrs.	500/1,000	2-5	nil	Top branches.
	Holmsley (Hants)	Be. 5-30 yrs.	5/440	25	nil	Base to top.
Dean	Cockshoot (Glos.)	SP 18 yrs.	1'3/1'3	20	nil	Top. No red squirrels.
	Serridge (Glos.)	Be. 20-25 yrs.	odd trees/ 20 acres	10-20	nil	Butt.
W.(S.)	Nethergwent (Mon.)	Bi. 20-30 yrs.	odd trees	..	..	Upper crown.
	Mynydd Ddu (Brec.)	Ash/Syc.	2/17	..	..	Very light. No details.
	Llanover (Mon.)	JL/SP 18-19 yrs.	odd trees/ 100 acres	..	nil	Upper stem. No red squirrels.
	Goytre (Mon.)	Syc. young	..	..	..	Slight attack on top. No details.
	Talybont (Brec.)	Syc. 31 yrs.	5/5	10	7	Leaders and branches.
	Llantrisant (Glam.)	Be. 33-34 yrs.	2-3 trees/ belts	..	..	Base of stem and some branches.
	*Crychan (Brec.)	SP 22 yrs.	16/16	12-15	12-15	Tops. Will be felled during next thinning.
W.(N.)	Coed Clwyd (Den.)	Syc. 20 yrs.	1/200	48	10	Crown.
	Radnor (Rad.)	Be. 30 yrs.	2/32	6/all	..	Butts and lower stems.

* The damage at Crychan is typically associated with red squirrels, which were present (but scarce) in the area. It is possible that this entry should be placed in Table XIII.

TABLE XII. *Damage Caused by Red Squirrels in 1955*

Forest Conservancy and forest	Spp. and ages attacked	Acres attacked/ present	Trees per acre attacked	Trees per acre useless	Parts attacked: comments
(a) <i>Squirrels numerous, damage light</i>					
E.(E.) Eleveden	SP 25-35 yrs.	..	..	..	Main stem, 2-3 in. diam.
Redneck	SP 0-25 yrs.	30/210	40	17	
	EL 0-25 yrs.		15	13	
W.(N.) Dovey Corris	PC 0-25 yrs.	1.5/?	200	50	Top half of main stem.
W.(S.) Crychan	SP 23 yrs.	10/10	33	33	Tops ringed.
(b) <i>Squirrels scarce, damage severe</i>					
W.(N.) Tarenig	SP 0-20 yrs.	1.5/2	12	12	Upper main stem.
	PC 0-20 yrs.				
	PC 0-20 yrs.	1/2	48	16	
(c) <i>Squirrels scarce, damage light</i>					
W.(S.) Cilgwyn	NS	4/20	20	0	Leaders cut off.
S.(N.) Strathnairn	SP 65 yrs.	odd trees/ 43.5	0	0	Leading shoots.
	NS 65 yrs.		0	0	
Aigas	SP 0-25 yrs.	0	0	0	Upper main stem.
Shin	SP 25 yrs.	..	5	0	Top 6 ft. main stem.
S.(W.) Devilla	SP P. 22 & 26	odd trees/36	0	0	Leading shoot girdled.
S.(E.) Elchies	SP 0-25 yrs.	0	0	0	Main stems.
Newtyle	SP 20 yrs.	..	..	..	Main stems.
Monaughty	SP 20-30 yrs.	..	..	..	Main stems.

TABLE XIII. *Damage Caused by Red Squirrels in 1956*

Forest Conservancy and forest	Spp. and ages attacked	Acres attacked/ present	Trees per acre attacked	Trees per acre useless	Parts attacked: comments
(a) <i>Squirrels numerous, damage severe</i>					
E.(E.) Elveden	SP 22 yrs.	200/250	10	1	Top 10 ft.
Redneck	SP 30 yrs.	40/115	45	20	Top 10 ft.
	SP/EL 30 yrs.	30/103	(SP 17 EL 9)	SP 17 EL 9	Top 10 ft.
(b) <i>Squirrels numerous, damage light</i>					
E.(E.) High Lodge	SP 25 yrs.	odd trees/2	1-5	1-5	Top 10 ft.
(c) <i>Squirrels scarce, damage light</i>					
W.(S.) Glyn Tarell	Be 4 yrs.	2/18	50	0	Stem (grey squirrels also present).
Crychan	SP 22 yrs.	16/16	12-15	12-15	Tops (attributed to grey squirrels).
S.(N.) Kessock	SP	2-3 trees	..	..	No deaths likely.
Balblair	SP 24 yrs.	15/250	25	5	Stem 2-3 ft. in diam.
S.(W.) Devilla	SP 30-40 yrs.	40/?	less 1 %	very few	2-3-year-old shoots.
S.(S.) Kilgrammie	SP	..	..	..	Crowns, slight.
S.(E.) Roseisle	..	..	..	..	Very light.
Midmar	SP 20-25 yrs.	5/22	4-5	0	Tops, very slight.
Faskally	SP 20-60 yrs.	odd trees	..	0	Crowns.
Fetteresso	..	..	..	..	No details.

PLOTLESS ENUMERATION WITH ANGLE GAUGES

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SUMMARY

The basic method and theory for determining basal areas with angle gauges are explained. Limitations in use are pointed out, and modifications and developments discussed. An explanation is given of the use of the angle-gauge principle for determining height and volume. Next, the instruments themselves are discussed and finally the Spiegel-relaskop and its wide range of uses. For the future, the author considers consolidation of ideas more likely than any very startling new developments. A full list of references to literature is given.

IT was in 1948 that an Austrian forester, Dr. Walter Bitterlich, first proposed the angle gauge method of estimating the basal area per unit area of a forest stand. Intense interest was aroused immediately, and in a very short space of time the method won wide acclaim for its simplicity, general efficiency, and, as shown by subsequent developments, its great versatility.

The object of this article is to review briefly the evidence on which these claims are based, and to describe the many types of angle gauges that have appeared in recent years.

I. THE BASIC METHOD

The method is essentially a sampling process, but one which requires no demarcation of sample areas, nor any direct measurement of tree stems. An estimate of basal area per acre is derived from a simple count of a number of trees that satisfy a certain requirement. In practice an observer selects in an unbiased manner a number of points within the stand, at each of which he sights a simple angle gauge at each stem in turn through a complete circle about his position. During this operation, the so-called 'enumeration sweep', the observer counts all trees with diameters at breast height subtending angles at his eye which are larger than the reference angle of the instrument, i.e. he counts trees which at breast height appear wider than the width of the gauge. Where, as will inevitably happen on occasion, breast height diameter and gauge width appear exactly equal, the observer counts and rejects these 'borderline' trees alternately. All other trees with breast height diameters apparently less than the width of the gauge are disregarded.

The estimate of basal area per acre at each sample point in the stand is given by simply multiplying the total tree count per sweep by a known constant called the basal area factor. Basal area per acre for the stand is then estimated as the average value per sweep.

The term first used by Bitterlich to describe this technique was the 'Winkelszahl' (angle count) method. Other descriptive terms now in general use are 'tree

count' method and 'plotless sampling' method, although neither of these is exclusive to the method in question. The term 'variable plot radius' method was adopted by Grosenbaugh (1952), who regarded the method as an ingenious adaptation to direct field use of the technique of point sampling, with each point on the ground being, in effect, the centre of a plot whose radius varied with the breast height diameters of the counted trees.

The theory of the method, which has been described also by Keen (1950), Spurr (1952), and Cromer (1954), can be explained as follows:

Let there be f_i trees per acre of radius r_i measured in feet. Then the basal area per acre of the stand will be

$$f_1 \pi r_1^2 + f_2 \pi r_2^2 + \dots + f_n \pi r_n^2.$$

In Fig. 1, let O be the position of the observer at one of the randomly selected sampling points. Let $2a$ be the length of the cross-piece of the instrument and b be the length of the rod, both measured in feet. Then 2α , the reference angle of the instrument, is given by

$$\tan \alpha = \frac{a}{b}.$$

Also, if R_i is the maximum distance within which trees of radius r_i are counted

$$\sin \alpha = \frac{r_i}{R_i}.$$

If z_i trees of radius r_i are counted from one sampling point, the estimated number per acre of trees of this radius will be

$$\frac{z_i}{\pi R_i^2} \times 43560$$

(since there are 43,560 square feet in one acre), and the estimated basal area of trees of this radius will be

$$43560 \times z_i \frac{\pi r_i^2}{\pi R_i^2} = 43560 z_i \sin^2 \alpha.$$

With trees of differing size the maximum distance within which they will be counted will vary, but the ratio of their radius to this distance is constant and characteristic of the instrument (or scale) used.

Writing $k = 43560 \sin^2 \alpha$, we have the total basal area per acre estimated from one point

$$\begin{aligned} &= k(z_1 + z_2 + \dots + z_n) \\ &= kZ \end{aligned}$$

where Z is the total number of trees counted in one sweep. For a number of sampling points, the estimated basal area per acre of the stand will be k times the mean count. The constant k , which as has been shown is determined by the reference angle 2α , is known as the multiplication or basal area factor of the instrument.

For very quick and rough estimates of basal area per acre, the forester's thumb can be used as a gauge. If t is the width of the thumb and b the distance from the eye at which the thumb can best be held vertical and still (e.g. at full length of arm) then the formula

$$k = 10,900 \left(\frac{t}{b} \right)^2$$

gives the approximate basal area factor in true measure. If the basal area is required in hoppus measure, the constant in the above expression must be multiplied by 0.7854, i.e. it should be 8,550.

Theoretically, angle count sampling is equally applicable to any forest stand, whether broadleaved or coniferous, even or uneven-aged, under- or over-stocked, but in order to apply the method successfully the combined effect of personal and instrumental errors must be overcome as far as possible. The method is dependent on a clear view being obtained of the stems to be counted, and this may be prevented by a dense shrub layer that overtops stem breast heights, or by the presence of many small trees in selection type forest. Stoffels (1954), Barrault (1955), and Viney (1956) discuss the less obvious difficulties that are commonly met in practice.

Of these, the observer's most common difficulty, especially in densely stocked stands, is caused by trees which should be counted being hidden by intervening trees which block his line of sight. Although a slight lateral displacement of the head generally suffices to bring partially concealed trees into clear view, there is always the chance that an incorrect count will be taken because some trees escape observation altogether. The difficulty of searching for trees in a restricted field of view, and the danger of bypassing a hidden tree, can be minimized by using a wide reference angle, and so shortening the radius of the sweep. On the other hand, in a poorly stocked stand an enumeration sweep of large radius is desirable to ensure a reasonable number of trees in the count. From recent work in Forestry Commission plantations of conifers, reference angles corresponding to basal area factors of 5 and 10 were found suitable for most fully stocked young to middle-aged crops. In mature stands and sparsely stocked pole crops a factor of 2 gave satisfactory results. Only for very dense crops in the first thinning stage was a factor larger than 10 necessary.

Inaccuracies in the count of trees may also result from the incorrect estimation of breast height. On steeply inclined or broken ground, and especially where undergrowth obscures the base of a tree, all but the most experienced observer will fall into error. Keen (1950) and Cromer (1952) suggest that a more accurate count is possible if an assistant is employed to mark breast height on trees during a sweep. No time need be spent on most of the trees, which can be clearly included or excluded from the count; marking would be confined to those stems where a slight error in estimating breast height could make the difference between being counted and rejected.

Similarly, comparison of gauge width and stem diameter at breast height presents no difficulties for the majority of stems sighted in a sweep. Ferguson (1951) has, however, shown that inaccuracies of up to 20 per cent. in the basal

area estimate can easily be made if the observer is not critical in his decisions regarding the doubtful trees. Genuine borderline trees will undoubtedly occur in any enumeration sweep and should be dealt with as described above, but an inexperienced or careless observer may be tempted to regard as 'borderline' the often considerable number of stems which cannot be quickly and easily classified. With a practised observer using an efficient instrument under good conditions there is a minimum danger of this occurring. However, for really critical enumerations, Grosenbaugh (1952) suggests an alternative but more laborious method of classifying doubtful trees: after what may be called 'the reliable count' has been taken, the instrument is dispensed with altogether and the observer relies on direct measurement of the theoretical plot radius for each doubtful tree encountered. If the point from which the sweep was taken falls within the circumference of a plot, then the tree relating to that plot is counted, and if the point falls outside, the tree is rejected. Where the point falls exactly on the circumference the tree will be either counted or rejected as a true borderline case. Senda and Maezawa (1955) also recommend the use of this method.

The angle count method eliminates the area basis of sampling in practice, but it is still necessary to correct for the slope of the ground at each sampling point. Failure to do so on slopes exceeding 5° will lead to serious errors in the basal area estimate. This requirement may be met in one of two ways. The first method is limited to sites where sampling areas fall on more or less uniform slopes. After each sweep a final overall correction of the basal area estimate is achieved by multiplying by the secant of the angle of slope, measured at right angles to the contours. On sites with more than one ruling gradient, correction for slope to individual trees becomes essential. Various angle gauges have been designed which accomplish this automatically. Descriptions of the instruments and their operating principles are to be found in Section III.

Bitterlich's angle count method has been widely tested in the field. In the United Kingdom, Keen (1950), working in even-aged plots of conifers, concluded that in such stands 15 to 17 enumeration sweeps gave an equally precise estimate of basal area per acre as the girthing of 14 one-tenth acre plots, and in less than half the time required for the girthing. Cromer (1954) tested the method over some 12 acres of even-aged pine plantations in Australia. The basal area estimate derived as the mean result of 10 random sweeps was within 2 per cent. of the estimate determined by girthing in an equivalent number of one-tenth acre plots, and within 3 per cent. of the actual basal area per acre as determined by girthing every tree in the test area. Further tests carried out by the Forestry Commission of New South Wales, but on a larger scale, confirmed the degree of precision which could be expected. The results of 94 enumeration sweeps, each taken from the centre of a quarter-acre sample plot, were compared with the basal area estimate determined by girthing in these plots. Differences between estimates by comparable plots and sweeps ranged from +5 per cent. to -10 per cent., with an average difference of +0.2 per cent. In Japan, Senda and Maezawa (1955), using a self-correcting instrument, tested the method in stands of conifers growing on moderate to steeply sloping sites. In each of six different stands the mean

result of six enumeration sweeps was within 2 per cent. of the basal area estimate as determined by complete girthing. Carow (1953) reports favourably on the use of the method in extensive stands of old hardwoods in America. The estimate of mean stand basal area per acre derived from a total of 50 enumeration sweeps did not differ significantly from the estimate obtained by girthing in one-fifth acre plots at the same locations.

II. MODIFICATION AND DEVELOPMENTS OF THE METHOD

The main disadvantage of simple angle count sampling as described in the previous section is that it gives the gross basal area per acre, and nothing else; no knowledge is gained of the number of stems per acre or of the girth class distribution in a stand.

Grosenbaugh (1952) suggests that in order to obtain this information the basic procedure should be modified by having an assistant to girth each tree that is counted in the sweep. Basal area per acre in each girth class is given by multiplying the count for each class by the basal area factor. The number of stems per acre in each class may then be computed for the total tree population, for individual species or for groups of species by dividing the total basal area per acre of the class by the basal area per tree. Shanks (1954) adopted this technique in an ecological survey of various Appalachian forest types. The survey was designed to give information on comparative density, frequency, size class, and basal area distribution for each of many intermingled species. He found the method to be much more efficient than conventional plot sampling; the yield of reliable information per man hour was several times as great.

The proven efficiency of angle count sampling has opened up a new approach to the estimation of standing crop volumes. Wanner (1948) describes a volume sampling technique based on a unit which he called a 'sample plot without a sample plot'. The method is simply a combination of his 'rapid circular-sample-plot' procedure (to determine mean height (h) and mean form factor (f)) and the basic angle count method (to determine basal area per acre (s)). Volume per acre at each sample point is calculated from the equation

$$V = s \times b \times f.$$

The combined procedure is claimed to be quick and to give reasonably accurate results.

Grosenbaugh (1952, (i) and (ii)) adapted the angle count method to speed up the large-scale volume sampling surveys practised in America. As each enumeration sweep is taken, the count of qualifying trees is recorded by both height and diameter classes, and the estimate of basal area per acre (s) is computed separately for each size class. Suitable volume tables, which are converted into form-height ($f \times h$) tables by calculating volume/basal area ratios for appropriate height and diameter classes, are then brought into use. Form heights corresponding to height and diameter classes recorded in the sweep are read from these tables, and volume per acre for each size class is calculated from the equation

$$V = s \times hf.$$

When all that is required of the survey is a simple estimate of gross volume, the cruising technique may be modified by adopting a mean value for form height within each height class. This eliminates the need for measuring breast height diameters during the count; trees need only be recorded by appropriate height classes.

Plotless cruising is particularly well suited to an area served by a local volume table based on the single variable of girth (or diameter) at breast height. The basic counting procedure need only be augmented by girthing or calipering qualifying trees; no height measurements are necessary. From the data recorded in each enumeration sweep, basal area per acre, number of stems per acre, and volume per acre for each size class can be computed.

Nyyssönen (1954) constructed special two-way stand volume tables for use with the angle count method, giving total volumes per hectare by known total basal area per hectare and mean height. They were quickly prepared from representative stands in the birch, pine, and spruce forests of Finland, as a preliminary to volume enumeration on a large scale throughout these regions.

To apply the tables to a particular stand, mean basal area per hectare was first estimated by a number of enumeration sweeps. Mean height was determined from an established top height/mean height relationship, with top height being taken as the mean of the heights of several of the largest trees measured in the areas covered by the sweeps. The corresponding volume per hectare for the stand was then read from the appropriate table. Nyyssönen considered the method to be at least as reliable as direct ocular estimation by trained and experienced assessors, and many times more efficient in rate of assessment than conventional plot sampling.

Cromer (1954) determined volume per acre for a stand by combining angle count enumeration with direct measurements taken on sample trees. At the site of each basal area sweep the breast height diameters of 15 to 20 trees are quickly measured and an arithmetic mean diameter calculated. Measurements of timber heights and diameters are taken on several sample trees which approximate to the mean diameter, and their volumes taken from commercial volume tables. The average volume per acre of the stand is then calculated by the following formula.

$$\text{Average volume per acre} = \frac{\text{average basal area per acre} \times \text{volume of sample trees}}{\text{basal area of sample trees}}.$$

The procedure was tested in some 600 acres of coniferous plantations, which were subsequently clear felled. The total volume of commercial timber determined by complete measurement of the felled stems was underestimated by less than 3 per cent.

The use of angle count sampling is not restricted to the horizontal plane. Hirata (1956) has adapted the method to the direct estimation of the mean height of a stand. In practice, the procedure is analogous to that followed when making a basal area enumeration sweep. A reference angle, held in a vertical instead of a horizontal plane, is compared with the angles subtended at the sampling point

by the total lengths of the trees surrounding the observer. The tree count (Z) then consists of those stems whose tops appear above the critical elevation. Mean height (h_m) is given in feet by the equation

$$h_m = \sqrt{\left(\frac{43560 Z}{n}\right)},$$

where n is the number of stems per acre in the vicinity of the sampling point.

The principle of the method can be explained as follows:

In a height enumeration sweep, represented diagrammatically in Fig. 2, $D/2$ is the maximum radius within which all stems of height H are counted. If the height of each counted tree is imagined to represent the radius of a circle in the vertical plane, then the area per acre of all such circles (g) is given by the equation:

$$g = \frac{\pi H^2 Z}{\pi (D/2)^2 1/43560} \text{ sq. ft. per acre.}$$

But $H = (D/2) \tan \beta$.

Therefore $g = 43560 \tan^2 \beta Z$ sq. ft. per acre.

The equation is valid not only for a stand of uniform height, but also for any mixture of heights occurring in a stand, for if $z_1, z_2, \dots, z_n$ trees with respective heights $H_1, H_2, \dots, H_n$ feet are counted, then

$$\begin{aligned} \text{Total circle area per acre } (G) &= 43560 \tan^2 \beta (z_1 + z_2 + \dots + z_n) \text{ sq. ft.} \\ &= 43560 \tan^2 \beta Z \text{ sq. ft.} \end{aligned} \quad (1)$$

The total circle area per acre (G) divided by the number of stems per acre (n) estimates the area of the mean circle.

$$\text{Therefore} \quad \frac{G}{n} = (h_m^2) \pi \text{ sq. ft.,}$$

and substituting equation (1) for G ,

$$\begin{aligned} h_m &= \sqrt{\left(\frac{43560 \tan^2 \beta Z}{n \pi}\right)} \text{ feet} \\ &= \tan \beta \sqrt{\left(\frac{43560 Z}{n \pi}\right)} \text{ feet.} \end{aligned} \quad (2)$$

If the instrument is constructed to define a limiting angle β of $60^\circ 34'$, then $\tan \beta = \sqrt{\pi}$ and equation (2) can be reduced to its simplest form, viz.

$$h_m = \sqrt{\left(\frac{43560 Z}{n}\right)} \text{ feet.}$$

The practical details of the method have not yet been fully investigated; preliminary reports of its application in even-aged coniferous plantations in Japan, where the technique was developed, are encouraging. In all except the

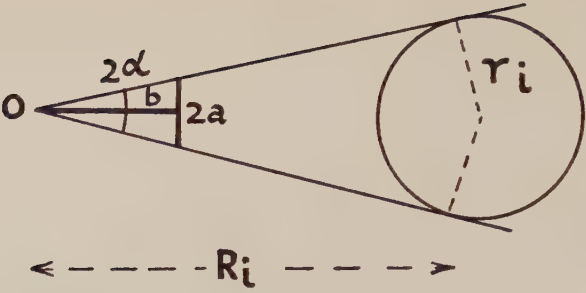


FIG.1

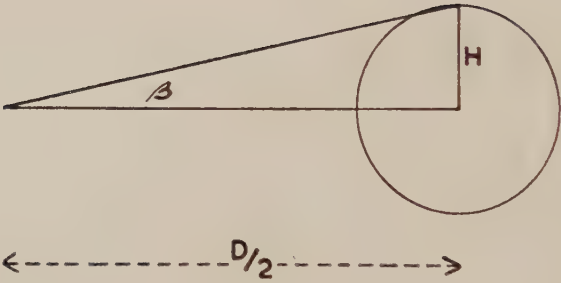


FIG.2

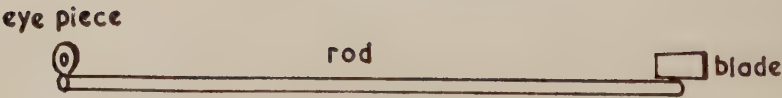


FIG.3



FIG. 4



FIG. 5

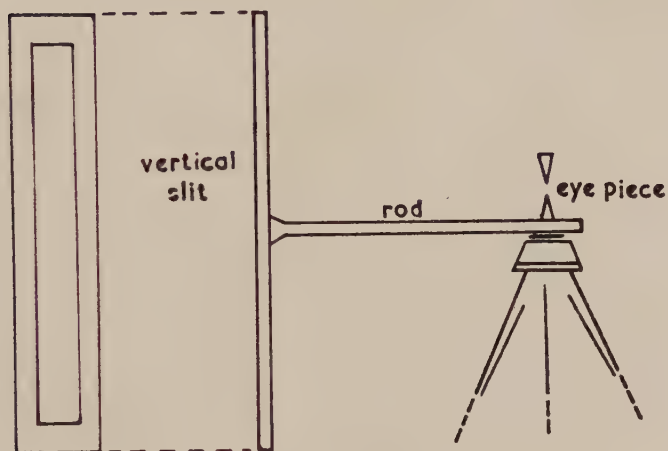


FIG. 6

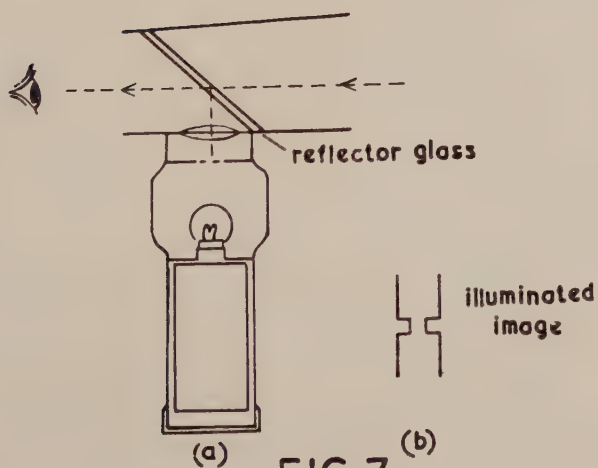


FIG. 7

most open stands, however, the difficulty will arise that the tops of many trees will not be visible from any given position. It should be noted that the estimate of mean height of a stand given by this method is the square root of the harmonic mean of the squares of the heights and thus differs from the mean height as calculated by conventional formulae. The differences and relative merits of each formula have recently been discussed by Bitterlich (1952, 1956 (ii)).

The same author (1956, (i)) has also described in detail the combined use of vertical and horizontal angle count sampling to determine the volume per acre of a stand—a technique which has been called the B-H method (B = Bitterlich for basal area and H = Hirata for height).

III. INSTRUMENTS

The original angle gauge designed by Bitterlich (1948) was extremely simple, and was known as a relascope. A metal blade 2 cm. wide was mounted at one end of a metre rod, and when in operation the other end was held just below the eye. The reference angle was given by the projection of the lines of sight from the end of the rod (i.e. the observer's eye) to the edges of the horizontally held blade. This simple form of relascope suffers from two major defects. Firstly, its use is limited to flat or uniformly sloping sites since no automatic correction for slope is provided. Secondly, the design of the blade makes it difficult to compare accurately the width of the blade and tree diameters, where these appear nearly equal, a defect which results in a high proportion of trees being regarded as 'borderline'. Nevertheless, simplicity of design is a big advantage, and with little or no modification this type of rod and blade instrument is in widespread use. Thonet (1948) incorporated the design into his patent 'Waldstock,' a multi-purpose tool which was converted into a simple relascope by elevating a small blade set at a fixed distance along the shaft. There was also an attachment for a type of clinometer which extended the use of the instrument to sloping ground, by providing direct readings of the required corrections for gradient. For general forest conditions in America, Grosenbaugh (1952) *et al.* recommend a rod length of 33 inches and a blade width of 1 inch, with the addition of a peep-hole sight to stabilize the position of the observer's eye. These dimensions give a most convenient basal area factor of 10. The instrument is illustrated in Fig. 3. Flemming (1954) gives details of the construction of a relascope made from a telescopic camera tripod leg and a small aluminium blade. The telescopic rod enables the reference angle to be changed to suit different stocking densities. Effective rod lengths of 33 inches and 46.6 inches are provided for use with a 1-inch sighting blade, giving basal area factors of 10 and 5 respectively. The blade is cut to leave small metal projections on the upper edge, spaced 1 inch apart only at their bases (Fig. 4). The inner edges are sloped, which makes it easier to decide whether doubtful trees qualify or not. West-Nielson (1952) describes a relascope used in Denmark which consists of a rod of fixed length (1 metre), but with a variable blade width. The blade is in the form of a thin, square, metal plate, centrally mounted on the end of the rod. Along each side of the square blade a section is cut out to form a shallow 'sight' (Fig. 5). These sights are 1 cm., 1.41 cm.,

2 cm., and 2.83 cm. wide, corresponding to basal area factors (in metric units) of 0.5, 1, 2, and 4 respectively. Although extremely simple these rod and blade instruments are quite satisfactory for most purposes. Indeed, Carow and Stage (1953) suggest that, as a rough and ready substitute, an outstretched arm with a thumb upturned will serve quite adequately as a relascope when the observer has forgotten to bring his instrument along. They give instructions for determining the basal area factor of the thumb, which generally approaches a convenient value of about 10.

With rod and blade instruments of the type described above, the precision of the final estimate will depend largely upon good vision and a steady hand, uniform configuration of the ground at the sampling points, and practice in distinguishing the point at which personal errors of judgement are liable to occur.

Bitterlich (1948) improved his original instrument by fitting an automatic slope correcting device, and by providing a choice of basal area factors. This 'pendel-relaskop' has been fully described and illustrated by Keen (1950) and Hummel (1951). The former also provides a table of instrument dimensions required to give direct estimates of basal area per acre in true and quarter girth units.

Senda and Maezawa (1955) also developed a relascope which automatically corrects for slope. Instead, however, of decreasing the width of the sighting blade to compensate for the increase, due to gradient, in the distance between observer and tree (which is what the 'pendel-relaskop' achieves), their instrument ensures that the rod length will vary in proportion to the slope. This is brought about by substituting for the blade a vertical slit of similar width (Fig. 6). With the rod of the instrument held horizontally on a tripod support, the breast height diameters of trees are sighted through either the upper or lower side of the slit, according to the slope of the ground, i.e. trees uphill from the observer would be viewed through the top half of the slit and vice versa. The width of the slit is adjustable, providing a wide choice of basal area factors.

Other instruments have been developed which depart markedly from the rod and blade design. Bitterlich (1948) describes two instruments with which he hoped to increase the speed and accuracy of the counting procedure. The simplest of these was a special pair of spectacles which supported at eye-level a simple angle sighting device, an arrangement which left the observer's hands free to record his own count. Seeking greater accuracy, Bitterlich modified an ordinary telescope to serve as an angle gauge in order to observe more critically the doubtful trees. Neither of these designs was very successful. Wearing the special spectacles, the observer suffered acute eye-strain, and with the telescope, although very accurate decisions were generally possible, the field of view was too small for rapid counting, and image illumination in dense stands was frequently inadequate. Grosenbaugh (1952) suggests a more refined version of this monocular type of instrument. This consists of a prismatic monocular with an internal scale graduated at 5-mil ($\frac{5}{1000}$ inch) intervals, thus providing a wide range of basal area factors. A convenient table is provided, giving the basal area factor corresponding to each graduation of the scale.

A unique instrument was designed by Cromer (1952) in Australia, which he called a reflectorscope. This instrument, illustrated in Fig. 7 *a*, combines the principle of the relascope with the optical properties of a reflector gun sight. The relascope blade is replaced by an illuminated image of a graticule (Fig. 7 *b*), which, by a system of lenses and reflectors, appears superimposed on the stem of a tree viewed simultaneously through the eyepiece. The instrument has some useful attributes: a steady hand is still a necessity, but the position of the eye may be varied at will without introducing parallax and altering the reference angle. Moreover no adjustment is necessary when the reflectorscope is to be used by a person wearing spectacles. Unfortunately, no provision is made for changing the inconvenient basal area factor of 4.36 to suit different conditions. Neither is there any automatic correction for slope.

A radical change in design was introduced by Müller (1953), who utilized the optical properties of a thin, wedge-shaped prism. When the stem of a tree is viewed through a prism of this type, the image of the stem is displaced laterally by an amount depending on the distance to the tree and the refractive properties or 'strength' of the prism. (Prism strengths are measured in dioptries, and prisms of the same strength have the same basal area factor, e.g. a prism strength of 2.0 dioptries corresponds to a basal area factor of 4.4.) When making an enumeration sweep, a tree is counted only when the lateral displacement of the image appears less than the diameter of the stem at breast height. The principle is illustrated diagrammatically in Fig. 8. When operating, the principal face of the prism must be held at right angles to the line of sight, and, on level ground, the top edge of the prism must be held horizontally. To facilitate correct positioning, Müller mounted the prism in a light, cylindrical tube so as to cover half the field of view. The instrument is known as a 'tree count tube' ('Baumzählrohr'). Cromer (1954) found that with this instrument confusion occurred between images and actual trees, leading to difficulties in counting and considerable eye-strain. He overcame these difficulties by fitting identical wedges to each objective of a low-powered binocular, a device which is claimed to reduce the number of borderline cases to a minimum.

To correct for the effect of slope with a prismatic instrument, the principal face of the prism must be rotated about the line of sight by an amount corresponding to the angle of inclination. In effect, this lessens the horizontal displacement of the image to an extent which exactly compensates for the increase in distance due to slope. Bruce (1955) designed an instrument which accomplishes this automatically (Fig. 9). A circular wedge prism is mounted on a horizontal shaft which is linked, by a system of gears, to a freely swinging pendulum. The whole is enclosed in a box, except for a segment of the prism which projects through the lid, and through which the trees are viewed. When inclined, the pendulum causes a rotation of the prism through an angle equal to the displacement of the shaft from the horizontal.

A non-automatic but nevertheless very useful instrument on sloping sites may be constructed by clipping a wedge prism to the barrel of an Abney level (Anon., 1955). The level and the prism are used alternately to each tree, the correct

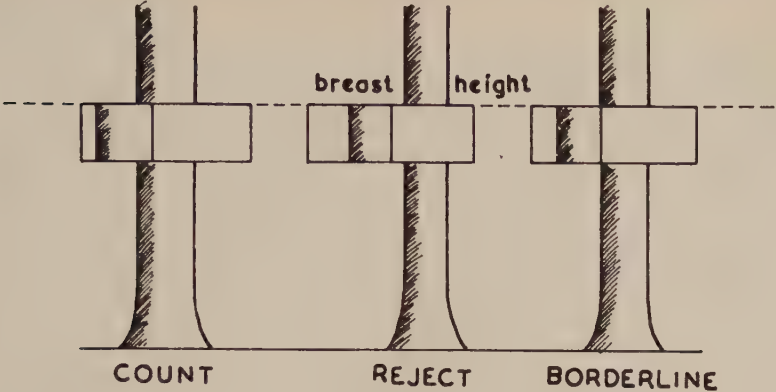


FIG. 8

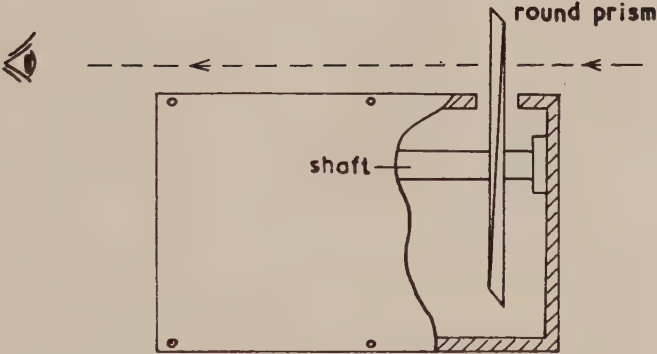


FIG. 9

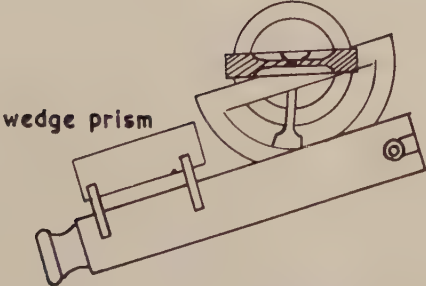


FIG. 10

position of the prism being fixed by keeping the bubble of the level centralized (Fig. 10).

Two difficulties arise with the use of these prismatic instruments. The 'rain-bows' around the edges of the image hinder a critical inspection of its relative displacement, and, unless the prism is specially cut for the purpose, the observer has to handle fractional basal area factors. The first difficulty can be eliminated entirely by using an achromatic (colour-corrected) prism. The second may be overcome by using a prism of adjustable strength, with the additional advantage that the basal area constant of an instrument may be varied to suit different size classes and stocking densities. Bruce (1955) has suggested a simple arrangement of two circular wedge prisms of different powers mounted on a common shaft. When the prisms work together their combined power is the sum of their individual strengths. When one is rotated 180° with respect to the other, the power is the difference of their individual strengths, whilst intermediate strengths may be selected by rotating less than 180° . An index on the periphery of the prisms would enable a convenient factor to be rapidly selected.

The precision and general refinement of optical instruments based on the angle count principle reached a peak with the development of the 'Spiegel-relaskop'. The metric version of this instrument was first described by Bitterlich (1952) and subsequently by Pardé (1956). Daniel and Sutter (1955) describe and illustrate a modified design developed for the American market.

The following section is an account of the British version of this instrument which was developed by Bitterlich to specifications suggested by the Research Branch of the Forestry Commission.

IV. THE SPIEGEL-RELASKOP

The mirror relascope has a much wider application in the field of forest mensuration than any of the designs described in the previous section. The estimation of basal area per acre by the angle count method is only one of its many functions. With a little practice the instrument can also be used efficiently as:

- (a) a hypsometer, to measure total or intermediate tree heights, in feet;
- (b) a dendrometer, to determine the girth of a stem in inches quarter girth at any height above ground level;
- (c) a range finder, to establish appropriate horizontal distances in feet;
- (d) a clinometer, to measure slopes in degrees or percentages.

The mirror relascope is sturdily built, but small and light enough to be easily held and operated with one hand. Fig. 11 illustrates the external appearance of the instrument when held in the operating position. Looking through a small, circular eyepiece at A, the observer obtains a clear, wide field of view through B. A movable shade C can be adjusted to cut off excessive light, while three circular, pearly-glass windows at D admit diffused light to the interior of the instrument. A small trigger E, when pressed, releases the brake controlling the movement of an internal scale wheel, which operates on the pendulum principle. The eyelets at F may be threaded with a strap for carrying the instrument, and at G there is a

tripod socket for setting up the instrument on a stable support for accurate readings.

The circular field of vision through A-B is divided horizontally into two equal halves by a system of mirrors. Tree stems are viewed through the upper half, while in the lower half the image of a series of vertical scales is simultaneously superimposed on the terrain. The horizontal division between upper and lower fields of vision is known as the 'measuring edge', at which all readings are made. No other point of reading is accurate.

The only internal moving part of the instrument, apart from the braking mechanism, is the pendular wheel, around the drum of which the scales are carried.

The ingenious design and arrangement of these scales is seen in plan view in Fig. 12. The key to the scales is illustrated more clearly in Fig. 13. This key is not normally visible when the instrument is in use, but tilting the instrument down 60° will bring the key into the lower field of view, where, by releasing the trigger, it may be locked whilst the function of each scale is studied.

Basal area estimation

Estimates of basal area per acre in quarter girth units are readily obtained by the angle count method. The principle is exactly the same as that described for other types of relascope, in that a simple angle gauge is used to determine which trees shall be counted and which rejected in an enumeration sweep. The mirror relascope offers a choice of four reference angles by providing four scales of different widths, each corresponding to a different basal area factor. The scales, since they are seen only by reflection, appear transparent, so that no part of the field of vision is obscured, and the breast height of stems can be estimated more accurately. These scales have a common edge which is marked 0 (Fig. 13). A scale width of 0-2 corresponds to a basal area factor of 2, and the 0-5 scale, 0-10 scale, and 0- ∞ scale correspond to basal area factors of 5, 10, and 20 respectively. The effect of the slope of the ground is automatically compensated by varying the width of the scales along their lengths (Fig. 12). The pendulum effect ensures that the measuring edge, which is aligned on the tree at breast height, cuts the scales at a point where the decrease in scale width (above and below the zero line) exactly compensates for the increase in distance, due to slope, between observer and tree.

Diameter measurement

A second series of scales provides a means of measuring stem diameters in terms of the equivalent quarter girths in inches. At a horizontal distance between observer and tree of 66 feet, these scales will accommodate stems up to 48 inches quarter girth, individual measurements being read to the nearest 4 inches and estimated to the nearest inch. For stems of 24 inches quarter girth and below, the accuracy of measurements can be increased by operating at a distance of 33 feet, at which setting quarter girths can be read to the nearest 2 inches and

estimated to the nearest $\frac{1}{2}$ inch. Increasing the setting to 99 feet would, if required, increase the accommodation of the scales to 72 inches quarter girth, but the accuracy with which readings could be made would be proportionately decreased.

To avoid possible confusion, the detailed description of the diameter scales which follows assumes a constant setting of 66 feet.

At this setting the distance between the scale margins *a* and *b* (Fig. 13) intercepts a diameter equivalent to 24 inches quarter girth. Half the scale width *a-b* is subdivided into three equal bands, two dark and one light, each of which represents 4 inches quarter girth. To the left of *a* and lying between the 5 and 10 basal area scales is a fine black line etched on a white background, and to the left of this line, between 0 and 2, runs a second fine black line. The distance from *a* to the nearest fine line increases the accommodation of the scale by another 12 inches quarter girth, and with the further addition of the distance between the fine lines; the maximum scale width equivalent to 48 inches quarter girth is brought into use.

To measure a tree with, for example, a breast height diameter equivalent to a quarter girth of 34 inches, the left edge of the stem is set on the fine line nearest *a*, and 24 inches quarter girth read up to the middle of *a-b*; a further 8 inches quarter girth are read on the first two 4-inch bands, and the last 2 inches quarter girth estimated on the third band. A few moments spent in studying the scales and a little practice in their use will show that this technique is not nearly so complicated as it sounds.

Since the instrument is self-correcting for change in slope, it follows that the quarter girth of a stem, not only at breast height, but at any height above ground may be determined.

Height measurement

Heights are measured in feet on the scale marked T, which is graduated to give a direct reading when operating at a horizontal distance of 66 feet from the tree. The scale is designed for measuring positive and negative heights and has the plus and minus directions marked on either side of the zero line. Fig. 12 shows the full range of the scale, which reads by 1-foot intervals to ± 100 and then by 5-foot intervals to +180 feet and -120 feet. The scale may be changed by varying the horizontal distance: at a setting of 33 feet each 1-foot graduation on the scale represents $\frac{1}{2}$ foot, and at 99 feet each graduation represents $1\frac{1}{2}$ feet.

By combining height and quarter girth readings, it is possible to read the quarter girth at the top of each log length or section up to timber point, or until the stem is obscured by the crown. The scales are so designed that the two readings may be made almost simultaneously: the eye simply changes from one scale to the other.

Range measurements

The built-in range-finder determines horizontal distances, regardless of slope, and in the minimum of time fixes the distances at which height and diameter readings are taken.

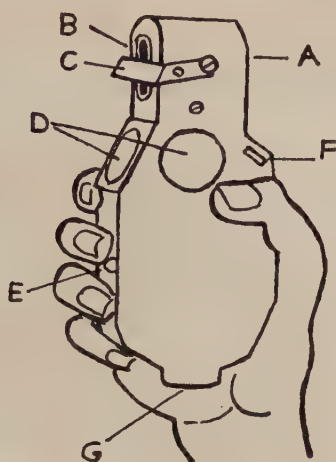


FIG. II



FIG. 12

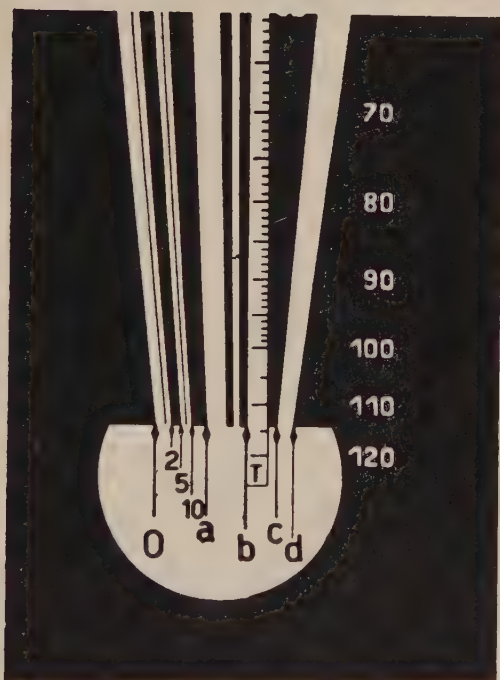


FIG. 13

The distance between the margins *b* and *d* intercepts 6 feet at a horizontal distance of 66 feet, and between the margins *b* and *c* intercepts 6 feet at a horizontal distance of 99 feet (Fig. 13).



FIG. 14

The method of using the range-finder to establish a 66-foot setting is as follows:

A white painted staff, exactly 6 feet long, is held vertically against the side of the tree. The observer takes a reading of the slope to the trees from an estimated distance of 66 feet, and the scale wheel is locked in this position. He then rotates the instrument until the measuring edge is vertical, and, by adjusting his position until the staff is just bracketed by the margins *b* and *d*, the correct setting is established (Fig. 14). The same procedure is used for the 99-foot setting, except that the scale distance *b* to *c* is used.

Slope measurement

Two useful topographical scales are also provided, marked D and P, running vertically along the extreme left of the field of vision (Fig. 12). Scale D is graduated to read slopes in degrees, with a range of $+70^{\circ}$ to -60° . Scale P reads slope directly as a percentage, with a range of $+270$ per cent. to -170 per cent. The height scale T can also be used to give the topographical corrections needed when measuring distances.

The mirror relascope has not yet been subjected to a full-scale field test. Preliminary investigations suggest, however, that in the hands of a practised operator the instrument may be used with confidence in all of its many roles.

V. LOOKING TO THE FUTURE

A review of a subject that has expanded so rapidly in the past would not be complete without some attempt to predict future developments. This task is made easier than it would have been a few years ago because interest now appears to be centred more on consolidating existing ideas than on developing new ones. This is particularly true of the various instruments that have been developed, for the forester already has at his disposal a wide range of designs to meet his specific needs. There is, however, one exception: at present there appears to be only one instrument for estimating mean height by Hirata's method, that described by Essed (1955). Apart from this one deficiency and possibly other minor improvements in design, there is little reason to suppose that the types of relascope available within the next 5 years will be very different from those in use at present.

The same conclusion is probably true of the future uses of the method, although here again further developments can be expected in the technique of vertical angle count sampling.

In Britain it is unlikely that plotless enumeration with angle gauges will ever wholly replace conventional methods, especially in precision work. The future of the method would, therefore, appear to lie mainly in combining angle count sampling in its simplest form with an orthodox system of sampling based on small representative plots.

ACKNOWLEDGEMENTS

My thanks are due to Dr. F. C. Hummel for the help he has given me throughout the preparation of this paper and to Mr. R. Howell for advice on the presentation of the theory of the angle-gauge method.

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THE ROYAL FORESTRY SOCIETY OF ENGLAND AND WALES

THE Society's 75th anniversary was celebrated in London in May 1957 by the planting of a tree at Kew by Her Royal Highness the Princess Royal and by a reception held at Londonderry House. The anniversary is commemorated appropriately in the July number of the *Quarterly Journal of Forestry*. Besides a foreword by the Society's President, Sir Richard Proby, this number contains an account of the celebration and two very interesting old group photographs of early meetings. There are articles by Lord Bolton, W. Dallimore, H. L. Edlin, C. P. Ackers, Langshaw Rowland, and N. D. G. James dealing in the main with progress and changes in the last half-century, while an interesting proposal for the future, since approved, is the establishment within the Society of an Arboricultural Section.

In spite of difficult times, the Society has never halted in its progress and we echo Sir Richard's wish that the Society may long flourish and may live 'to see in this country a forest economy which, though limited in size, will bear comparison in quality with any in the world!' The Society has already made a considerable contribution towards securing this.

SEVENTH BRITISH COMMONWEALTH FORESTRY CONFERENCE, 1957

THROUGH the courtesy of the Forestry Commissioners, we have been able to include in this number, which went to press before the opening of the Conference, the names of the delegates from the United Kingdom and the titles of the papers prepared in the United Kingdom for the Conference. By the same means we are able to print in this number a paper presented to the Conference by Mr. A. Watt.

The conference was timed to take place in Australia and New Zealand between the 26th of August and the 10th of October. Sessions were at Adelaide, Canberra, and Auckland. Extensive tours had been arranged in Australia, Tasmania, New Zealand, and in New Guinea.

Delegates to the Seventh British Commonwealth Forestry Conference

United Kingdom

Sir Arthur Gosling: Director General, Forestry Commission.
Mr. J. Macdonald: Director, Research and Education, Forestry Commission.
Mr. G. B. Ryle: Director of Forestry for Wales.
Mr. C. D. Begley: Secretary, Commonwealth Conference Standing Committee.
Mr. C. Swabey, Colonial Office Forestry Adviser.
Dr. F. Y. Henderson: Director, Forest Products Research Laboratory.
Mr. R. G. Miller: Director, Colonial Air Survey.
Professor M. L. Anderson: * Edinburgh University.

Imperial Forestry Institute

Professor Sir Harry Champion†

Commonwealth Forestry Bureau

Mr. F. C. Ford Robertson

Empire Forestry Association

Mr. W. MacFarlane Robertson

Papers for the Seventh British Commonwealth Conference prepared in the United Kingdom

<i>Item</i>	<i>Title of Paper</i>	<i>Author</i>
4	Imperial Forestry Institute 1947-56	Professor Sir Harry Champion
	The Work of the Commonwealth Forestry Bureau 1952-7. A Progress Report	F. C. Ford Robertson
5 (i)	European and Near East Experience in Planned Land Use as affecting Forestry	J. J. Macgregor
	Planned Land Use and the Classification and Dedication of Land for Forestry	Sir Henry Beresford-Peirse
5 (ii)	Desirable Balance between Hardwood and Softwood Production in Great Britain	Professor H. M. Steven and W. M. McNeill
6 (i)	Exotic Forest Trees in Great Britain	J. Macdonald <i>et al.</i>

* Associate Delegate.

† Sir Harry Champion is representing this Society at the Conference.

<i>Item</i>	<i>Title of Paper</i>	<i>Author</i>
6 (ii)	Improvement of Scots Pine in Britain by Selection and Breeding	J. D. Matthews
6 (iii)	The Effect of Rate of Growth (Ring-width) on the Density of Softwoods	B. J. Rendle and E. W. J. Phillips
7 (i)	The Planning of a Management Unit	F. C. Osmaston
7 (ii)	The Problem of Unmerchantable Species in the Management of Tropical Forests	W. A. Gorden
7 (ii) (b)	Potentialities of Savanna Woodland	Eustace W. Jones
7 (iii)	The Use of Aerial Photographs in Forestry in the British Colonies	R. G. Miller
8 (ii)	Recent Observations on the Rusts of Pine in Britain	T. R. Peace
	Top Dying of Norway Spruce	J. S. Murray
	Diagnosis of Mineral Deficiencies in Tree Crops	L. Leyton
8 (iii)	Australian Quarantine and Wood Boring Insects	R. C. Fisher
	Experiments in the Control of the Pine Weevil, <i>Hyllobius abietis</i> L.	Myles Crooke
9 (i)	Developments in Pulping and Board Manufacture in Great Britain	A. Watt
	The Production of Hardboard from Tropical Woods	D. F. Packman
9 (iii)	The Grading of Hardwoods in the British Commonwealth	A. H. Lloyd
10 (i)	Problems and Technique in Forestry Research	Forestry Commission
10 (ii)	Is Present-day Forest Products Research Meeting the Needs of the Forester?	O. J. Sangar
	Is Present-day Forest Products Research Meeting the Needs of the Timber Trade?	Bryan Latham
12	Some Thoughts on Higher Education in Forestry	Professor Sir Harry Champion

HONOUR

In Her Majesty's Birthday Honours List. Mr. A. H. H. Ross, lately Director of Forestry for Scotland, to be Commander of the Most Excellent Order of the British Empire.

SILVICULTURE (JOSEF KÖSTLER)

Review by J. ALAN B. MACDONALD

THAT Professor Anderson considered this 1949 book on silviculture* worth translating means that it is an important work. As the publisher's note points out, there was need for an authoritative, up-to-date textbook on the subject in English. It is slightly ironical, however, that it should be provided by a German authority, for in his own country Professor Köstler has been a voice crying in the wilderness, the naturalistic practices he commends being much more in evidence in Switzerland and Austria. Köstler became Hitler's Director of the International Centre of Silviculture at Berlin in 1939 and remained there until 1946. The preface touches on the literature cited, which is large—420 authors—and mainly in German. Köstler explains how his book consists largely of his lectures and cites as the most important task in silvicultural lecturing 'to arouse in the beginning the understanding that the forests are living communities'. He pays tribute to Gayer many times; indeed there is considerable hero-worship and ancestor-worship throughout, although to be fair Köstler does not shut his eyes to criticism of his country's general shortcomings as regards forestry in the past—'Pessimistic voices are not lacking which deny Silviculture the right to live under German conditions'.

In an Introduction, 'Silviculture and its position within Forestry as a Science' is considered. The idea that silviculture meant only 'planting, tending, harvesting and replanting' is blamed for 'mistaken attitudes' and for 'destroying over wide areas the healthy structure of forests' leading to 'catastrophes by storm, snow and insect'. 'Silvicultural theory must proceed from natural forests.' 'It was a gross error to suppose that in the forests man could "govern" Nature.' 'Silviculture has also been justifiably described as an art, as a special sort of proficiency in which intuition plays an important part.' 'The concept of sustention is the dominant one in organised forestry.' The prescribed cut is the driving force in silviculture; 'the claims of sustention permeate all the economic and technical divisions of organised forestry'; stand diagnosis is a prerequisite in silviculture; silviculture is forestry therapy; these are strident aphorisms in the Introduction—this book has many such.

Part One begins with 'The concept of the forest as a living community' which is the new gospel, utterly opposed to the old German mechanical outlook which treated the forest merely as a productive enterprise firmly controlled by man by net yield formulae and general prescriptions. This mechanistic outlook readily adapted itself to capitalistic and bureaucratic systems and it is still the standard one today! According to the biological gospel, forests are members of a natural universe, living phenomena renewing themselves in perpetual harmony uninfluenced by man. The forester should be concerned to imitate natural processes and to be distrustful of the commercial outlook as being dangerous for the forest's well-being. Although silviculturists in other lands must welcome this healthy retreat from the overorganized nature-forgetting forestry which did untold harm in Germany and beyond, one cannot help feeling that Köstler's fervid arguments will fall on many who are already long converted.

Chapter III on 'The Forest Trees' deals with life processes and is apparently based

* *Silviculture*. By Josef Köstler, Professor of Forestry, Munich; translated by Mark L. Anderson, Professor of Forestry, Edinburgh. Oliver & Boyd, Edinburgh, 1956. Pp. 416. Price 45s. net.

largely on Busgen, Munch (1927). There are good paragraphs on each of the common species but the writer has little good to say of exotics. One can't help wondering if the lack of success with them is not largely due to the stiff mechanistic attitude which we hear so much about in this book, i.e. to the fact that to the majority of German foresters an exotic was simply a tree and ought to work to rule. Possibly there was insufficient thought of selecting exotics from regions or sites truly likely to be suitable for the planting sites in central Europe. The fact that Sitka spruce is in the list makes this appear very likely! The impression is given that Köstler himself has a feeling that some exotics may yet do in Germany, but he goes to great lengths to air all the heavy arguments of his countrymen against their use. The reviewer recalls a remark made by a great arboriculturist about the natural bent certain nationalities had for gardening and tree-growing—Germany was not high in the list. Almost certainly the new species were tried out in the main as pure crops in a part of the Continent where monoculture of native species was the rule. Would trial under more natural, non-mechanistic treatments in mixture not have had very different results?

Even reforestation of areas denuded of trees generations ago need not be, and seldom is, done in a hard, heartless manner with complete indifference to the lessons which mere common sense must glean from a knowledge of—among other things—natural woods. One can hold therefore that silvicultural art—the 'proficiency in which intuition plays an important part'—may certainly develop during the forestation period, and that it is crass snobbery to pretend, as some continental authorities do, that no forester dealing with woods in their first rotation has the right to consider himself any more than a mere *planter*. We in Britain must hold hard to the ideal that we are creating forests for all time with their associated micro climate; creating a living organism which will provide a sustained yield and not simply aiding and abetting the timber-merchant-minded who can conceive of nothing higher than planting a wood to cut it down when the return in hard cash will be highest, without a thought, far less a tear, for the glorious habitat developed and so lightly wrecked.

Chapter IV on 'Forest Sociology' attempts to show how life in the forest goes on under such a multitude of influences and deals with the new phase in silviculture which has sprung from plant sociology and the forest sociological outlook. The study of forest types is said to be an attempt to make the living forest community comprehensible to human intelligence by classification. Forest types from Cajander's are dealt with. Chapter V 'Upsetting of the Biological and Ecological Balance by Man' consists of two pages only. In it Locker estimates that Switzerland's forests ('a model for World Forestry') could increase yield by 70 per cent. if there was optimal growing stock on all areas. The main results of man's interferences are listed as (1) spruce and pine too widely spread; (2) failure to realize value of sustained attention to soil and stand; (3) and (4) unsuccessful pure stands; (5) foolish litter utilization; (6) disappearance of leaf trees; (7) stands ruined for game. This is the end of Part One and the last paragraph summarizes much that has gone before. Every interference with inherent natural laws in the forest involves a serious change in ecological conditions. Silviculture must be regarded as 'tending' to obtain improved ecological conditions and increment production. 'Responsibility towards coming generations' requires 'loyalty towards sustention'. Finally what the forests need are 'strong personalities who will implement the necessary principles'. 'Any man who is called to practice silviculture professionally cannot escape meditation on these matters.'

In Britain all Forestry Schools now pay considerable attention to the many factors which influence tree growth in the forest. Oxford led in this respect; certainly Ray Bourne, before 1930, was hammering home the lessons to be learned from ecological study, and

Anderson himself had published a little booklet on British Forest Types by this time. We have, however, less reason to be proud of our record for disregarding natural laws of the forest in our plantings and clear fellings. For even if we admit the necessary and catastrophic war fellings—how many of us knew better or felt keenly enough that other and less vandalistic methods of reaping and replenishing were possible? Loyalty towards sustention scarcely existed then; do we yet possess the 'strong personalities' so truly required?

Part Two begins with an introductory word on 'Silvicultural treatment as interference with living communities' and redefines silviculture as 'biologically controlled technology' incited by an economically prescribed objective. Every teacher must oppose rigorously all attempts to 'generalise and systematise the art of silviculture' . . . 'such bureaucratism inimical to the forest'. Silviculturists today should be 'forest nurses and physicians in sick forests'; they need education in diagnosis and quite general therapy.

Today many British foresters will endorse Köstler's definitions of silviculture and his fervid belief that bureaucratism is inimical to the forest, heartily supporting his view on the dangers likely to result from attempts to 'generalise and systematise the art'. The idea that the silviculturist's main function is to diagnose conditions and apply remedial treatment will be well supported. No young officer can have enough training in forest diagnosis and therapy. Very rapidly too the best young British foresters are tending towards selection as the treatment for many of their woods. Indeed to treat his favourite stands otherwise is anathema to the man who loves his woods. Gradually, too, more silviculturally sensible ideas on stand tending are spreading and the idea of thinning as something crudely between *increment reaping* and *suppressed tree removal* is now less often met with. More and more good foresters annually learn to appreciate the real advantages given to a stand by a thoughtful and never harsh or over-strong removal of trees in all canopy levels but especially in the top one in order to let the best stems develop even more favourable crowns and generally to develop a deep, undulating and healthy zone of foliage and a forest floor in a vitally healthy state.

In much the same way the keen silviculturist at home wishes to introduce more species because of certain helpful functions they may provide such as vegetation suppression, or the better utilization of half-light, or the provision later on of a floor in ideal condition for a seed-bed. In this connexion has anyone ever seen a stand suffer from too many species? It is impossible, for the forester always has the control of the mixture in his own hands.

Chapter VIII on 'Regeneration of Stands' runs to over fifty pages and deals with the subject both in general and in detail not for the first time. One gets the impression that the writer is very much a professor, very full of general principles and a trifle shaky on detail or practical application. Natural regeneration we are told 'as an end in itself is to be deprecated' and it is interesting to learn that Köstler believes that artificial regeneration operations may make for healthier growing stock in mishandled forests. As there are few forest areas in Germany which have been treated to date in a manner which would meet with the writer's approval, every encouragement to go on with good artificial regeneration is given. 'Each of the true basic systems (of natural regeneration) displays defects'; in the shelter-wood coupe there is the risk of failure of seed years; clear felling leads to exposure of soil and is rarely possible; the marginal system delays the fellings and does not altogether favour the young crop. For these reasons the systems are seldom found in the pure form, but almost always combined to some extent. Gayer is said to have been a pioneer of combined methods. In Bavaria the 'femel coupe' was ruined by overdoing the orderliness, whereas in Switzerland 'freedom from every system resulted in a vast improvement'. It is well to note the remark that 'complete natural regeneration of whole stands is very rare'—under German conditions no more than 10 to 20 per cent. Foresters in Britain are

probably less likely than their continental brethren to let a desire for natural regeneration go to their heads, if for no other reason than their excellent experience in forming woods artificially and expeditiously. But one is well aware of the intense interest and often quite undue importance given by keen foresters and owners to the first sporadic seedlings of a species which appear in their woods. On the other hand, foresters of more experience recognize to their cost the *nuisance* which scattered individuals of a sparse, inadequate natural regeneration can develop into later on.

Is it possible that over-keenness is the forester's worst fault and that this is the reason for the many so-called silvicultural systems appearing flawless to their originators and practically unworkable (if one sticks to the code) to anyone else? Otherwise why should it be that in such a country of good foresters as Switzerland 'freedom from every system resulted in a vast improvement'? To me this is perhaps the most significant line in the book. It suggests that what we require are officers and foresters and woodmen so well trained in diagnosis and therapy that each *in his own sphere* makes a flawless diagnosis and as a result applies, at the first opportunity, treatment which is consistently right—not only in itself but in so far as the well-being of the soil and the perpetuity of the forest is concerned. In the simplest of words, give complete authority to skilled, well-trained men to act as they believe best and the forest and the sustained yield therefrom will flourish in every sense: curb these men by imposing systems and long-term regulations and, though the Working Plan may be followed, nothing is more likely than that the forest will suffer. The Forestry Commission must be given considerable credit for the latitude given to its officers in this respect, and for the indications that even when the new plans of management are introduced these will not be allowed to hamper at any time the application of the obviously most sensible silvicultural treatment.

This may be a much-needed textbook in Germany, yet it is difficult to imagine its being accepted as an authoritative manual of silviculture in Switzerland, Austria, or France, where the silvicultural ideal had attained this level years ago even if it was not there set down so relentlessly and with such repetitive insistence. Full credit must be given however for what is none the less the best piece of synthetic work on forestry that has been produced for a long time. 'It is extremely difficult', Professor Anderson commented when shown this review in draft, 'to determine (here) what are really important advances in forestry and to say whether certain developments can be accepted . . . in Germany this is possible because of the considerable background of experience which they have, and also because of the fairly extensive area of natural forest or semi-natural forest. Köstler's book is valuable to us in Scotland because he is dealing with an area which is in many ways similar to our own and dissimilar from the rest of Germany. Hence, I suppose, his attitude towards silviculture.'

Until someone provides a new English textbook on silviculture—and why should it not be Professor Anderson himself?—this book will fill a gap in English-speaking countries, tending to steer us away from the crude mechanistic ideas of clear felling and low thinning which have long cursed our forestry, to say nothing of forestry in Germany. The translation reads well and the photographs are excellent.

REVIEWS

Adelges Insects of Silver Firs. By I. W. VARTY. Forestry Commission Bulletin No. 26. 1956. Edinburgh: Her Majesty's Stationery Office. Pp. 75 with 70 photographic plates. Price 8s. 6d. net.

Review by MYLES CROOKE

MANY of the exotic conifer species now widely used in British forestry have had introduced with them a variety of non-indigenous insect pests, but usually the attacks of these pests are not limiting factors in the economic cultivation of the host trees in Britain. The best-known exception to this rule is the crippling effect of *Adelges nusslini* C.B. infestation on the common silver fir, *Abies alba* Mill., which now precludes the use of that valuable and desirable tree as a forest crop in this country. Dr. Varty's studies on *Adelges nusslini* and the very closely related *A. piceae* Ratz., as reported in this Bulletin, are thus of considerable practical significance as well as being of great academic interest.

The work is soundly based on a review and confirmation of the taxonomic status and life cycles of the two species. In investigating the former topic an original contribution has been made in the use of paper chromatography to differentiate closely allied species, and, as Dr. Varty hints, the technique may well prove of wider value in studying the taxonomic relationships of the Adelgid group as a whole. The rearing and observation of all stages of the five generations of *A. nusslini*, which alternates between silver fir and *Picea orientalis* Carr., and of the generations of *A. piceae*, which is restricted to silver fir, is no small attainment and provides full confirmation of the details of this complex type of development.

From this basis the author passes to consider the reaction of the tree to attack, and discusses the anatomical and chemical derangements which result from infestation. It is a logical step to treat next the resistance to attack of species and individuals of the host genera. The phenomenon of host resistance to attack by various Adelgid species is of common occurrence but the mechanism of resistance has never been adequately explained. Dr. Varty attempts to show that resistance may be associated with lower zones of pH in the resistant species or individuals but the data presented are hardly conclusive enough to prove this theory. In particular the distinction between cause and effect appears to have received but little attention. It is unfortunate, too, that in this section minor inconsistencies appear in the flow of argument (cf. text p. 55 and Appendix 5). Certainly, as the author admits, much further work is required here before the hypothesis can be substantiated; but at least an interesting line for speculation and for further investigation has been brought to notice.

The final section is devoted to a discussion of the forest status of the silver fir *Adelges*. Although *A. piceae* can be considered of secondary importance, *A. nusslini* must be regarded as a primary pest of such virulence that the formation of stands of *A. alba* remains a most risky proposition. Whilst it may be worth while to attempt some small experimental plantings of *A. alba* to gain further experience, British foresters must still in general resign themselves to finding alternative species for sites which they think would and should carry the common silver fir.

The Bulletin is copiously and in general well illustrated, but a few of the photographs

reproduced are of poor quality. Dr. Varty is to be congratulated on completing such a painstaking and informative piece of work, and the Forestry Commission for producing its first major entomological publication in 20 years.

Genetics in Silviculture, by C. S. LARSEN. Translated by M. L. Anderson. Oliver and Boyd, Edinburgh, 1956. Pp. 224. Price 30s. net.

Review by J. D. MATTHEWS

NOWADAYS there is a widespread and rapidly increasing interest in the application of genetics in silviculture. Most forest research stations have a forest genetics or forest-tree breeding section and there is a good deal of individual research on these subjects in progress in many countries. At least two institutes have been established specifically for forest genetics research and there are several State supported and privately financed foundations for forest-tree breeding. In Germany a periodical devoted to forest genetics and forest-tree breeding began publication in 1951. In America the expansion of work in this field has been very rapid during the past 5 years and in particular a number of regional Forest Tree Improvement Conferences have been held to bring together geneticists, silviculturists, and those concerned with the utilization of timber to study ways of producing superior trees.

In 1956 there were more than fifty full-time forest geneticists and forest-tree breeders in Europe; in 1926 their number in the world could be counted on the fingers of one hand. There was also at that time a general disbelief in the feasibility of applying genetics in silviculture. Much of the credit for the present world-wide recognition of the importance and possibilities of forest genetics and forest-tree breeding must go to the author of this book, Dr. C. S. Larsen of Denmark. In his earlier papers, principally those of 1934, 1937, and 1945, Dr. Larsen wrote of the development of the principles and techniques of forest-tree breeding. Now we can read of the successful application of these principles and techniques in a book that has been written for specialists, for students, and for 'anyone who feels the obligation to promote forestry'. There is no doubt that specialists will gain much from this book. For students the book is easy to read but not quite so easy to refer to. I would have preferred the literature references together rather than scattered through the text, and students would benefit from a glossary of terms.

For the general reader this is a very readable account of forest-tree breeding and forest genetics and should capture the interest of a wide public. The book is well produced on good paper, the type is clear, and the illustrations are well reproduced. So far as I can judge the translator has preserved the author's style intact (I have not had access to the original text), and but for the choice of the term Progeny Trials for Provenance Trials as the title for Chapter III and one or two minor errors, Professor Anderson must be congratulated on his work.

Some of the facts about early work on hybridization and the vegetative propagation of forest trees given in Chapter II, entitled 'Retrospect', will surprise many readers. The first known intentional interspecies hybrids of forest trees were produced in 1845, just over 110 years ago. These hybrids together with Luther Burbanks' Walnut hybrids of 1877 and 1878, and Augustine Henry's first poplar hybrid *Populus 'generosa'* produced in 1912, failed to stimulate much interest among the foresters of the day. The spontaneous hybrid larch *Larix eurolepis* was the first species hybrid to be widely used in practical forestry. The history of vegetative propagation in forestry is also surprisingly long. In 1826 Corsican pine was being grafted on to Scots pine by the thousand for planting in the

Forest of Fontainebleau and clones of *Cryptomeria japonica* produced by the rooting of cuttings have been used in Japanese forestry for more than a century.

In Europe and elsewhere considerable increases in the productivity of plantations have been obtained by the use of exotics. This has also led to the appreciation of the importance of seed origin and to provenance research which has in some cases begun to yield valuable results. That both the use of exotics and provenance research have continued importance is well demonstrated by Dr. Larsen in Chapter III. Here he critically examines the use of climatic criteria in selecting sources of imported seed and concludes that strict climatic matching cannot often be obtained and need not necessarily be demanded. He suggests that other site factors and the quality of the trees themselves should be taken into account.

The obstacles to the application of genetics and the techniques of breeding to increase the productivity of forest trees were threefold. The first difficulty was the size of the trees and the consequent remoteness of the flowers. The second was that of the often large distances between suitable parent trees, and the third was the slow succession of generations, especially in species such as beech and oak. The answer to all these problems was shown by Dr. Larsen to lie in the use of vegetative propagation as a primary technique, and the methods of forest-tree breeding now generally employed are based primarily on vegetative propagation. The procedure may be summarized as follows:

1. Parent trees (superior phenotypes) are selected in natural woodlands and in plantations.
2. These trees are propagated vegetatively, by grafting or by the rooting of cuttings, to form clones.
3. The clones of grafted plants or cuttings are planted in comparative trials (tree shows) and are used to estimate the genotype of the parent trees.
4. When the grafted plants or cuttings flower, controlled pollination is used to combine parent clones of the same species (intra-specific hybridization) or of different species (interspecific hybridization) to determine these combinations which produce superior progeny.
5. Seed gardens (seed orchards) are established with the best parent clones to mass produce seed of the best combinations. In practice the work under 3, 4, and 5 is carried out simultaneously. To save time seed gardens are established with untested parent clones and the unsuitable parent clones are removed as the testing and crossing programme develops.

The book begins with a summary of the aims and methods of forest-tree breeding and goes on (Chapter II) to discuss and appraise the work done by the pioneers since the days of Duhamel du Monceau (1760). Next follows a discussion of the value of provenance trials. The following two chapters (IV and V) are devoted to the two principal techniques of controlled pollination and vegetative propagation. The purposes, layout, and management of 'Seed Gardens' (seed orchards) are described in detail in Chapter VI and figures are given for the production of seed by the larches, Scots pine, and ash. The valuable information which can be derived from clones planted in 'Tree Shows' is well brought out in Chapter VII which is followed by a chapter on the problems and possibilities of breeding for disease resistance. Next comes a section on hybrids (Chapter IX), then one on Genetics (Chapter X), and in a penultimate chapter the application of the various techniques and breeding procedures are demonstrated by describing the work done in Denmark on the breeding of larch.

In his final chapter, Dr. Larsen emphasizes that forestry is still in a primitive state and that the machinery and techniques available for felling and utilizing trees are still far more

efficient and highly developed than those used to re-establish the forest. He shows that some of the apparent difficulties of tree breeding are in fact advantages. In particular good genotypes, once identified, can be preserved indefinitely by vegetative propagation and there is also not the same need for uniform progeny as there is in agriculture—in fact the aim is to maintain diversity in some characteristics.

It is 20 years since Dr. Larsen grafted his first ash for use in improvement. Now seed gardens composed of graftings of the best female and male trees are producing seed for forest use. After about 25 years of breeding work with the larches 'we are now getting near to the practical application of the results of improvement'. Dr. Larsen points out, however, that the work with other species will not take so long to achieve similar results because the necessary techniques are now known and trained people are available and have the equipment for the work. There are now promising indications that the inbreeding-outcrossing procedure so successful with hybrid corn can be applied to larch with similar beneficial results.

In conclusion I can say that it has been a pleasure to read this book and I have no hesitation in recommending it 'to anyone who feels the obligation to promote forestry'.

Treasury of Trees. By H. L. EDLIN and M. NIMMO. Countrygoer Books Limited, Old Colony House, Manchester, 2, 1956. Pp. 318 and 380 photographs. Price 75s. net.

Review by the EDITOR

FOR inclusion in this beautiful book, the authors have selected those trees growing in Britain which 'the reader will be most likely to find in parks and gardens, orchards and avenues, as well as along the hedgerows and in old native woods or more recent plantations'. Altogether 140 trees have been pictured and described including all common native trees and all those extensively planted.

In Part One, the broadleaved trees are for the most part pictured in summer with more detailed photographs of the flowers, fruit, and sometimes the bark. Some but not all are shown in winter. The authors stress the importance of knowing the more constant features such as the shape and arrangement of buds and the shape and disposition of leaves and give some examples showing differences between the leaves of different species and differences between bare twigs and buds. At the end of Part Two which describes conifers, two pages are devoted to photographs of seeds. The pictorial presentation, which has the major role in this book, is entirely photographic. All the photographs were taken in Britain by M. Nimmo working either with the living tree or with material newly collected therefrom. H. L. Edlin provides a commentary, picking up the main points likely to secure identification and, in addition, drawing shortly on his wide knowledge of tree history, tree names, and tree use.

The presentation is good and there are very few failures, though the difficulty of obtaining convincing photographs in summer foliage is considerable. The fact that many people without any particular scientific training are happier looking at photographs than at line-drawings fully justifies their use, but the photographer is at a serious disadvantage in showing differences in detail, and in this case the fact that no scale has been used has not made his task any easier. Edlin has come in for some criticism on account of the dimensions given for some trees, and this shows the keen interest taken about individual tree measurements and reveals that there is no authentic published list to which a writer or other interested person can refer. So the new bulletin published by the Forestry Commission on exotic forest trees in Great Britain is very welcome, and it is to be hoped that ways and

means can be found to publish in one place the details known to have been collected over the last 30 years about native trees as well.

A principal object of the book is 'accurate identification by all available characteristics at every season of the year', and the combination of photography and commentary aided by the careful arrangement and planning should secure this and attract to a first study of trees many who would be shy of studying line-drawings and botanical keys for identification. The book is costly but will be in demand in libraries. Its study will do much to increase interest in trees and in the countryside.

British Trees: A Guide for Everyman. By MILES HADFIELD. J. M. Dent & Sons Ltd., 10-13 Bedford Street, London W.C. 2, 1957. Pp. xxv+468 with 150 full-page diagrammatic drawings. Price 30s. net.

Review by A. F. MITCHELL

MR. HADFIELD is well known both for his accurate botanical drawings and as a historian of gardening. These attributes are well combined in this book. There are articles on 119 species fully treated, with 150 full-page drawings of twigs, leaf-sprays, flowers, fruit, seeds, and often seedlings and also leaves of varieties, with many additions of details. They are the result of careful study of specimens most of which have been raised by the author. They are detailed without being fussy and give an attractive and clear impression of the species at a glance. That of the shoot of Sitka spruce and the page of the Tulip tree are particularly pleasing, to mention only two. The one exception is that the spray of Western Hemlock strikes one as sparse for this species, and in that way resembles the Eastern Hemlock. An unusual and attractive feature is the inclusion of stages of germination and top views of cotyledons, and some characteristic features like the long projections on the young leaves of Red oak.

Any book written for an interested but inexpert public has to compromise between simplicity and completeness, and so, like an anthology, comes under fire from reviewers for omission of favourites and unworthy inclusions. In this case selection has to be so rigorous that it must have been difficult indeed, for such a large number of species is grown in Britain and so many are liable to be encountered in gardens and parks by anyone looking for trees. One has the conviction that, as in books on wild flowers, the reader, fired with enthusiasm to see species hitherto unknown, will go straight out and find species and varieties which are not in the book. This likelihood is diminished here by a selection of broadleaved trees which I cannot criticize, and among conifers I have but two candidates for omission and four for inclusion, perhaps at the expense of two broadleaved. My two dispensable trees are the Stone pine and Maritime pine. My combined personal records for these species totals 13 trees and I regard them as extremely rare in collections, parks, and gardens. I find *Pinus ponderosa*, however, frequently and have measured 41 good specimens to date, so would have liked to see this included. I miss *Abies nordmanniana* too, of which I have 76 personal records and which is usually such a fresh, healthy, and shapely tree. Among the spruces the author treats Norway and Sitka fully and mentions *Picea pungens glauca* in the text. This last is far commoner in residential areas than is Sitka, however, and I find the Oriental spruce present in most collections—I have measured three times as many as Stone and Maritime pines combined. Perhaps the position is akin to that in bird books, which seem to feel incomplete without the Wryneck, which is picturesque but now one of our rarest birds, yet often overlook, for example, the common Lesser Redpoll.

Since even simple keys rather frighten the layman, Mr. Hadfield has relied on the drawings speaking for themselves, which they do admirably. Identification will then be a matter of matching the specimen with the drawing, and if one has no knowledge of likely families this may take time, for the book, very sensibly, is arranged in botanical order. For one who has some botanical knowledge and suspects a specimen belongs to a certain family, identification will be rapid. The details and insets of hairs, toothed margins, cross-sections of twigs, and floral parts will ensure that one is not led astray by superficial resemblances.

The treatment of difficult genera like *Ulmus* and *Populus* is concise, up to date, and very satisfactory, the text giving information on some clones and varieties which might be confused with the major ones illustrated. Alternative views on classification are given and only in one case would one have adopted an alternative, for there is much to be said for accepting the Cornish and Jersey elms as distinct clones of *Ulmus carpinifolia*.

The text is extremely interesting reading. There is a concise botanical description, mainly to stress certain points and give colourings which cannot be conveyed in the illustrations; an account of the natural range and sizes achieved within it and excellent historical notes. All the more interesting or usual varieties are mentioned and useful notes given on the vigour and hardiness of seedlings. In the matter of the largest specimens in Britain it is never possible to be absolutely up to date, but this book does very well. It is no fault of the author's that the Douglas fir at Powis has just been climbed and found to be, at 181 feet, probably taller than the Silver fir at Inveraray. I would, however, like to see both *Abies grandis* and Sitka spruce credited with trees of 160 feet, while many are above 140 feet.

There is a good synonymy and many vernacular names for every species which has any, and, similarly, Welsh and Gaelic names are included. There is a very good glossary of botanical terms, and the index is complete even to Gaelic and Welsh names and every place and person of even the most passing mention. This rounds off a book which is well produced and invaluable to anyone in any way interested in trees.

Studies of North-West American Forests in relation to Silviculture in Great Britain.

By R. F. WOOD. Forestry Commission Bulletin No. 25, London, H.M.S.O., 1955. Pp. 42 with 35 photographs and a map. 6s. net.

Sitka Spruce in British Columbia. A Study in Forest Relationships. By W. R. DAY.

Forestry Commission Bulletin No. 28, London, H.M.S.O., 1957. Pp. 110 with 57 photographs. £1 net.

Review by EUSTACE W. JONES

EXOTIC conifers from North-western America have become so important in British forestry that the value of a knowledge of their native habits and habitats, about which surprisingly little exact information is available, is obvious. It is therefore very satisfactory that recently two British foresters with wide experience of these trees planted in Britain have been able to study them in their native forests more closely than is possible for the average traveller, and have consequently published the two bulletins which are reviewed here. Mr. Wood spent nine months travelling through country ranging from Alaska to the Columbia River, thus acquiring a broad picture of the pattern of the Coastal forests; Mr. Day, on the other hand, spent four and a half months in two small areas making detailed studies centred on Sitka spruce. Thus the two bulletins are very different in character, and are in a sense complementary, the one general, the other specialized.

Mr. Wood's bulletin is evidently the product of his reading about some particularly important aspects of the forest and its environment, together with his general impressions and comments on various matters which affect the use of the coastal forest trees in Britain. Thus a considerable part of the bulletin merely brings together and summarizes matter previously published elsewhere. Almost a third of the space is devoted to an interesting study of the climate, in which Mr. Wood demonstrates very convincingly the fallacy of the common assumption that the Pacific coastal climate resembles that of Britain: even though it is possible to match curves for mean monthly temperatures for particular localities in the two countries, the distribution of rainfall is almost always very different and tends to produce far drier conditions in the Pacific coast summer than we experience in Britain.

General notes—often all too brief—on the individual species stress the bearing on British practice of the author's observations. A final chapter of considerable though rather more specialized interest discusses matters of provenance—both the sources of the seed which has already been planted in this country, and alternative sources of potential value. In general the bulletin is very readable and could only be criticized on matters of detail; for example, one wonders on page 18 what depths of soil would impress Mr. Wood; and I am sorry to see that 'data' has become so singular that it has now developed a double plural 'datas'! Every British forester should find the bulletin interesting; the North American forester will find in it nothing that matters to him save some suggestions for satisfying European seed-requirements.

Mr. Day's bulletin is of a much tougher consistency, and is meant for specialists only. It reproduces a wealth of detailed observation on sample plots, which are described, as they should be, very fully. Many of the details—e.g. the exact localities, the species composing the field and ground layers, &c.—will be appreciated only by those who know the forests. Such material does not make for easy reading, and the difficulty is increased by the author's preference for unusual words and constructions. Thus the word 'regression' is freely used in the sense of a 'gradation' or 'transition'—a usage which would puzzle any reader unacquainted with statistical terminology, and one for which no justification can be found in the *Oxford Dictionary*. The word 'proportionate' is used in contexts where its appropriateness is at least questionable. For reasons such as these many sentences had to be read more than once, at least by me.

There is an immense amount which should provoke serious forest ecologists to thought in the bulletin, which is important as a contribution to the study of virgin temperate forest. Most of the observations are interpreted in accordance with the author's ideas on the relation between soil properties, acting through their influence on root growth, and the health and growth of the tree. Obviously in an old unworked forest a stage must eventually come, even on the best of sites, when trees dying of old age will be found; many of these dying trees will be dominants, and they will exhibit dieback of crowns and roots and other 'pathological symptoms'. To attempt to explain the existence of 'pathological symptoms' in such forest is the same as attempting to explain the ultimate causes of senility and death. There are passages where I felt that these essential facts were being overlooked, though the concluding discussion shows that the author is perfectly clear about them. Any fundamental criticism of the work would have to discuss these ideas about the way in which site affects longevity—a task which is far beyond the scope of a short review. Personally I do not feel completely convinced of the truth of the hypothesis that rate of growth, vitality, and longevity vary together. The most that I can attempt here is to draw attention to some conclusions of general interest.

Windthrow and fire are both important destroyers of forest and initiate more or less

even-aged stands of regular character, but old undisturbed stands are pictured as becoming open-canopied and eventually irregular in structure; some are said to be 'all aged'. The opening out of the stand with age is ascribed to the increasing volume of soil, and hence of the area, needed to support the ever-enlarging tree (it could conceivably be due to the vegetation of the field layer preventing regeneration). Soils are often rendered shallow either by rock or by badly aerated substrata; the surface organic matter ('mor') often forms an important part of the rooting-medium. Sitka spruce appears to be a more exacting species in respect of its soil-requirements than either of its chief associates, *Tsuga heterophylla* or *Thuja plicata*, and there seems to be little justification for the optimism with which it has been so widely planted in Britain. Highly developed podsol such as are frequent in Britain are absent from the Pacific Coast, and exposure to wind is far less severe than in Western Britain. It is striking on how many of the above matters Mr. Wood and Mr. Day agree, despite their very different approach.

Both bulletins are lavishly illustrated with photographs, which together with the numerous tables doubtless explain the high price of bulletin No. 28.

A Handbook of Hardwoods. Department of Scientific and Industrial Research. Forest Products Research. H.M.S.O., London, 1956. Pp. 269. Price 17s. 6d.

A Handbook of Softwoods. Department of Scientific and Industrial Research. Forest Products Research. H.M.S.O., London, 1957. Pp. 73. Price 8s. 6d.

Review by L. CHALK

THESE two handbooks are direct descendants of the *Handbook of Empire Timbers*, which was so useful in the 1930's, when so many new timbers and new names appeared in this country. This publication was superseded in 1941 by two volumes, one on overseas and one on home-grown timbers. In the two handbooks under review the grouping of the subject matter has again been changed, with all the hardwoods, whether imported or not, grouped together in one volume, and all the softwoods in the other. This seems a more satisfactory arrangement from several points of view.

The general plan adopted has been to give a separate description for each timber. In addition to a short account of the tree and where it grows and a general account of the timber, there is a great deal of useful information grouped under such headings as Mechanical Properties, Natural Durability, Preservative Treatment, Resistance to Insect Attack, Working Properties, Veneer and Plywood, and Uses. This covers everything that one is likely to want to know and is thoroughly up-to-date, but, of course, the data available under each heading vary considerably for each wood. Much of the technical information has been derived from tests at the Forest Products Laboratory, Princes Risborough, and at other similar research institutions. Though the skeleton is rigid it is notable that within each section the format is flexible and is determined entirely by what there is to say. A very helpful feature is that pertinent comparisons with other timbers are made for the reader, without the necessity of looking up other descriptions. This is particularly useful in sections such as Mechanical Strength, where such comparisons mean much more to the ordinary reader than the actual figures obtained from tests.

Much more information is contained in the present handbooks than was available in 1941 and many of the timbers that were then relatively new and untried have since shown their paces in actual use, and can now be accurately assessed for different purposes. For their size and price these two volumes represent remarkably good value for money.

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LITERATURE REFERENCES

Up to the present time, the details of literature referred to in papers published in *Forestry* have been collected in lists alphabetically at the end of the paper and the items numbered serially. Only the serial number of the reference has been given in the text itself.

It has been pointed out that it is more usual, and in many cases more convenient, to have the name of the authority and the year of publication *in the text*. The list of references at the end of the paper is then arranged alphabetically by authors and by years of publication but is not numbered.

It seems proper to fall in with normal practice and the 'name-date' system has therefore been followed in this number and should generally be followed in future except in special cases, e.g. where an exceptionally long list of references might make the system too cumbersome.

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